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ABSTRACT

This report describes the activities of a program designed to develop the information and systems necessary for managing the Continental Shelf and Coastal Zone of Northern New England. Ten research areas or projects are discussed: aquaculture, biology and ecology, coastal oceanography, buoy systems studies, man in the sea, marine platforms and controls, preparation and dissemination of information related to ocean engineering, pollution hazards, sea-bottom resources, and the Undergraduate Oceans Project Course. Studies related to each of these areas are presented and include a brief description of the research, progress of the research, and principal investigators. (MH)

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MARINE RESEARCH ANNUAL REPORT

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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THE UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE

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UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE 03824

OFFICE OF THE PRESIDENT

A Message from the President

The University of New Hampshire's historic involvement in marine research and education dates back to 1927, and is consistent with the fact that its Durham campus is one of the few in the nation located close by an ocean coast.

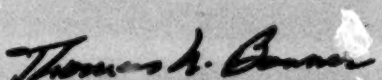
The University, in 1965, undertook its present major commitment to marine affairs when it drew upon the expertise of its faculty and staff in the area of marine studies, the ocean-engineering focus of its Engineering Design and Analysis Laboratory, and the support of the federal government's National Science Foundation to establish the Jackson Estuarine Laboratory on Great Bay, just a few miles from the main campus. The Jackson Laboratory and the Engineering Design and Analysis Laboratory (whose activities are described in this report) have now been joined by several other support structures—including the University-wide Marine Affairs Committee which advises the administration on marine policy—to strengthen and broaden the University's overall competency in marine affairs.

Contemplating the commitment and contribution of many of the University's faculty members to marine affairs and the growing national recognition of their efforts, the University Board of Trustees in 1973 asked the New Hampshire Legislature to establish a special Marine Program Budget to provide basic support for continuing this educational, research, and service program. This welcomed and much-needed new budgetary support had barely been initiated when the University was called upon to play a major role in advising the Governor's Office and other state agencies on the implications of locating an oil refinery and related off-shore terminal in New Hampshire's coastal area.

We can expect that in the years ahead the critical need for energy, the changing role of the fishing industry in our coastal waters, and the federally-legislated requirement for extensive coastal zone planning and management will further prove and enhance the importance of the service our Marine Program provides to the people of New Hampshire and the region as well as giving our students the skills and orientation to take advantage of the growing job opportunities in the marine area.

Much of our Marine Program development must be credited to the support provided by the National Sea Grant Program under the National Science Foundation and, more recently, the National Oceanic and Atmospheric Administration. Although the Sea Grant Program provides only about 40 per cent of the external funds supporting the University's marine efforts, it has been the catalyst for transforming several individual faculty research efforts into an overall University Marine Program with related support and services. The other federal, state, and industry sponsors of our Marine Program are duly noted at the close of the project and program descriptions in this report.

It has been a source of personal satisfaction and deep pride to be associated with the Marine Program during my tenure as President of the University of New Hampshire. I congratulate my marine colleagues on their successful efforts and their dedication to this vital aspect of man's environment, and I trust this will be but the first of many Marine Program Annual Reports in the years to come.



Thomas N. Bonner
President

Directors' Comment

This annual report represents the efforts of faculty, students, and staff associated with the Engineering Design and Analysis Laboratory (EDAL), the Jackson Estuarine Laboratory (JEL), the University of New Hampshire-Raytheon Industry-University cooperative Sea Grant research project, and the University of New Hampshire Coherent Area Sea Grant Program, which includes the Marine Advisory Service. This year, as a symbol of the continuing growth and service, it was decided to join the annual reports of these different organizations into a single document in order to reflect the major marine commitment that the University has made.

Other marine projects and programs not related to any of the organizations reporting herein are being carried on at the University of New Hampshire. Although these activities are not described in this document, they are a valuable part of the University's marine program. Nevertheless, we believe that this report does reflect the breadth and strength of the University's efforts in marine activities and we are proud to be able to introduce this report on the activities of our faculty colleagues and their associated students and technical staff.

Barbaros Celikkol
Director,
UNH-Raytheon Sea Grant Project

A C Mathieson
Director,
Jackson Estuarine Laboratory

Godfrey H. Savage
Director,
Engineering Design and Analysis Laboratory
Director,
UNH Coherent Area Sea Grant Programs

University of New Hampshire Coherent Area Sea Grant Program

The University of New Hampshire Coherent Area Sea Grant Program was initiated in 1971 as an outgrowth of previous individual Sea Grant supported projects at UNH commencing in 1968. The UNH/CAP Sea Grant Program has grown steadily ever since to where it now incorporates the efforts of over 20 faculty and their related technical staffs and students. The program focuses upon developing the information and systems necessary to develop and manage the Continental Shelf and Coastal Zone of Northern New England. So far the three major efforts have been in developing engineering data and systems in anticipation of increased power plant construction and development of the offshore oil industry, both drilling and tanker transportation; mariculture with emphasis on Coho salmon, blue mussels, and certain seaweeds, and some work with the lobster industry; and environmental monitoring and control. It is intended that the program be developed further in the areas of recreation and coastal zone planning support. Both of these are of significant importance to the future of the state of New Hampshire and its sister states of Maine and Massachusetts.

Engineering Design and Analysis Laboratory

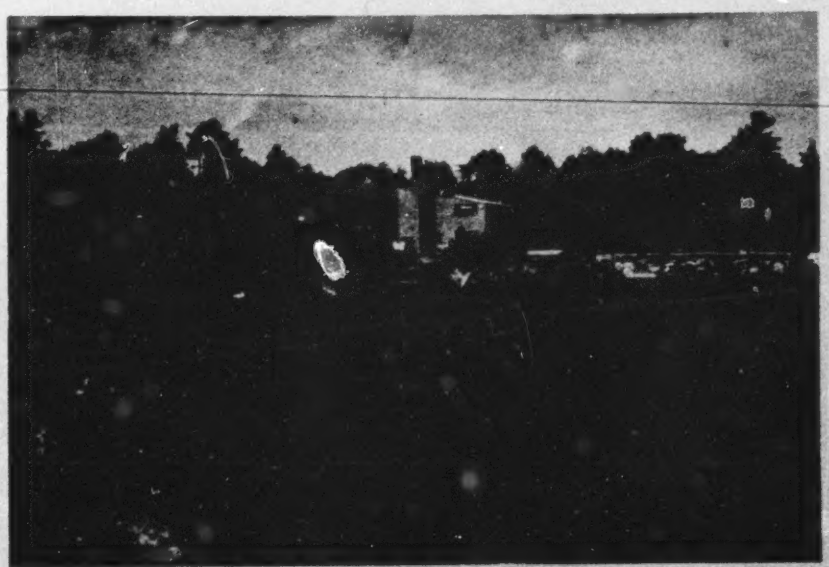
The Engineering Design and Analysis Laboratory was founded in 1965 by a group of Mechanical and Electrical Engineering faculty for the purpose of providing the students and themselves with the opportunity to work on real engineering problems in the service of industry and government. This laboratory, called EDAL, is based upon the philosophy that a good engineer must be well versed in the disciplines of mathematics, physics, and the other analytical skills necessary to understand today's advanced engineering, but he or she must also be able to synthesize and apply these skills from original conception through the analysis, engineering design, construction, and final field testing of his or her own innovations that will better the society in which we live. As the Engineering Design and Analysis Laboratory has developed, the focus has been primarily on ocean related problems because the ocean environment provides the breadth of areas of application and the need for innovation that is consistent with EDAL's goals. Also, faculty from Chemical and Civil Engineering, as well as faculty from non-engineering departments, have joined with the original faculty to provide the continuity and commitment that are necessary to persuade University faculty to take an interest in technical leadership and result-oriented goals as well as the publication of papers for scientific or professional journals.

The Jackson Estuarine Laboratory

A Research Facility for Marine Scientists

The Jackson Estuarine Laboratory is a marine research facility located five miles from the main campus of the University of New Hampshire at Durham. The laboratory was dedicated on May 30, 1970 and was named for Professor C. Floyd Jackson, a member of the Zoology Department at the University of New Hampshire from 1910 until 1946. In addition to his teaching in the Zoology Department, Professor Jackson was for many years its head and later became Dean of the College of Liberal Arts. He conducted summer courses in marine science at the Isles of Shoals for many years.

The laboratory is dedicated to the understanding of living chemical and physical phenomena in our estuarine environment and the Gulf of Maine. It is an 8,400 square foot structure, all laboratory space excepting 600 square feet for administrative purposes. There is a running sea water system with salt water of approximately 70 per cent full-ocean salinity available at all phases of the tide from channel water just off the laboratory property. The laboratory is provided with a con-



The Jackson Estuarine Laboratory Near Great Bay

ference room, 45-foot research vessel (R/V Jere A. Chase), and a 100-foot stone faced pier. Its personnel includes faculty and graduate students from five departments of the University: Biochemistry, Botany, Earth Sciences, Microbiology, and Zoology.

The Sea Grant Marine Advisory Service at the University of New Hampshire

The National Marine Advisory Service was established by the National Oceanic and Atmospheric Administration (NOAA) to provide the necessary link between research institutions and interested users. The need for such an advisory service became apparent as knowledge of the oceans and the coastal zone rapidly expanded, and as marine research grew, spurred by increased levels of federal funding. Following a precedent set by the Land Grant Act which started the Cooperative Extension Service, the Office of Sea Grant early in its development encouraged the establishment of local advisory service components at each institution funded through the Sea Grant Program. These advisory units were charged with assimilating the vast amount of information generated from marine research, and making this information available to marine industry, governmental agencies, and the general public.

The Sea Grant Marine Advisory Service at the University of New Hampshire was started in the fall of 1972. Its initial approach was not oriented toward the traditional approach of personal contact with individuals, but rather toward stimulating projects and activity in selected program areas among university personnel, private industry, and state agencies. This strategy was based on the belief that once programs were started the benefits would invariably become available to the public. Efforts are presently being concentrated on a limited number of projects of local and regional significance, particularly in aquaculture and fishery sciences, coastal zone management, and environmental areas. As the level of marine activity in the state increases and diversifies, the scope of advisory efforts will be widened accordingly.

University of New Hampshire-Raytheon Sea Bottom Resource Project

In the spring of 1970, the Office of Sea Grant Programs, National Oceanic and Atmospheric Administration, began supporting a university-industry research and development project which integrates the technical talents of faculty and students at the University of New Hampshire and of professional and technical personnel of the Submarine Signal Division of the Raytheon Company. This project differs from many university-industry teams (i.e., client-consultant or client-vendor relationships) in that it is based on a shared leadership in a fully integrated research effort, building on the different resources of two quite disparate organizations.

Solution of the somewhat unusual management problems attendant upon the university-industry relationship is a part of the project. This engineering project is concerned with the creation of an improved acoustic technology to classify and assess the coastal sea floor and subbottom sediments for both physical and engineering properties. This highly integrated inter-institutional project was conceived as a response to national needs for research from a broad perspective of the technical, ecological, legal, economic, and management understandings which are essential to responsible exploration and utilization of the country's continental shelf sea floor natural resources.

Aquaculture

A Preliminary Study of Flounder Culture

Principal Investigator:
Professor Philip J. Sawyer

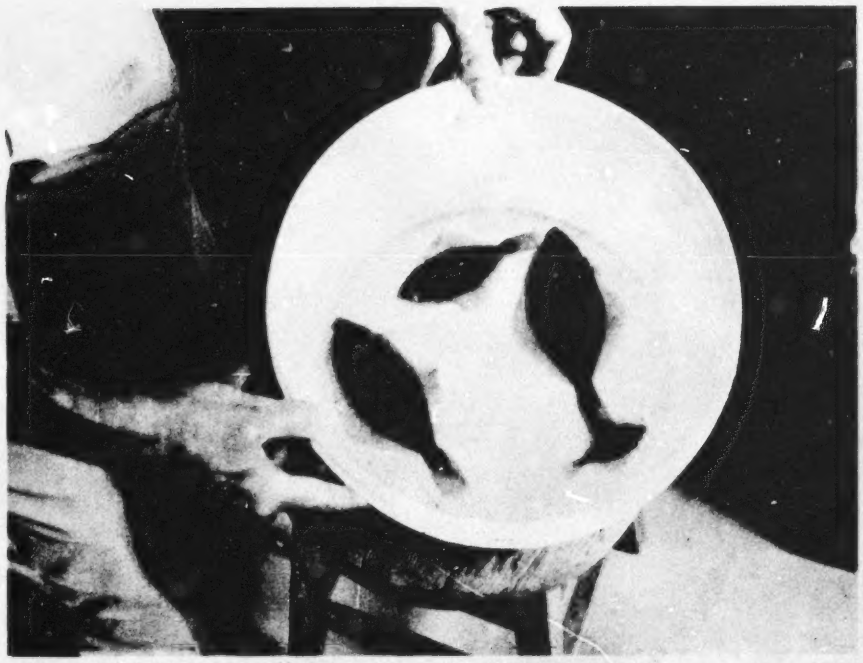
Associate Investigators:
Professor Donald M. Green
Dr. Evelyn S. Adams

The objective of this study is to undertake pilot studies on rearing Winter flounder with improved characteristics by genetically selecting the Winter flounder to improve growth characteristics. This study was undertaken with a view toward eventually supplementing natural populations and improving the marketable catch. A study of rearing flounder in heated effluents from power plants is intended.

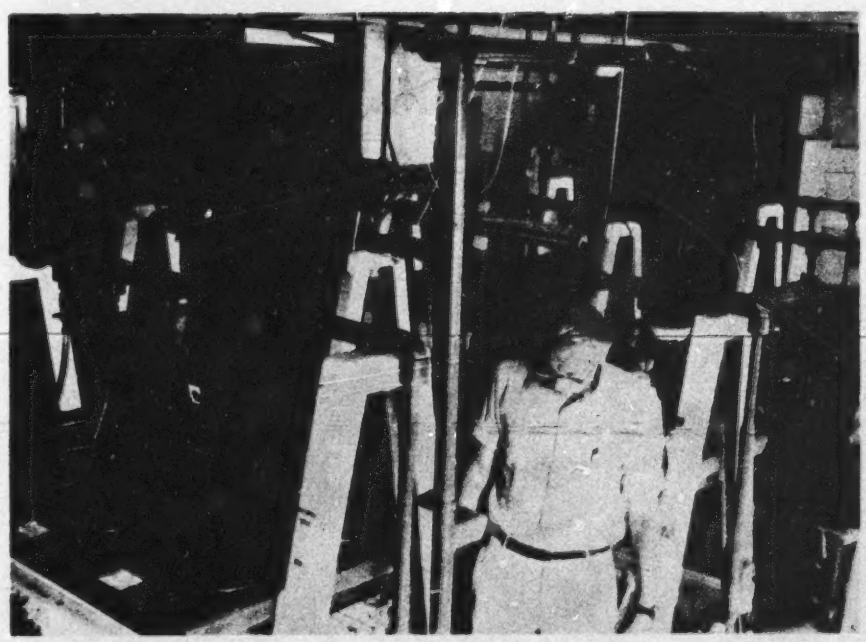
If these studies are successful in improving the strain of Winter flounder it may be possible to develop a variety of Winter flounder suitable for aquaculture purposes. A potential industry may be developed. It may also be possible to duplicate these objectives using the Smooth flounder.

In a preliminary Winter flounder egg culture study at Jackson Estuarine Laboratory, siltation and salinity variation in the sea water were found to have an adverse effect. Further investigations are being made.

· Sponsored by Sea Grant No. 04-3-158-38.



Size Variation in Young Flounders. Two Age Classes Are Represented.



Running Sea Water Facility at the Jackson Estuarine Laboratory

Development of a Salmonid Fishery for Coastal New Hampshire: A Pilot Program—The Rearing of Coho Salmon

Principal Investigators:
Professor Richard G. Strout
Professor Richard C. Ringrose

Associate Investigator:
Mr. Erick D. Sawtelle

Graduate Student:
Mr. Richard H. Sugatt,
PhD Program in Zoology

Undergraduate Students:
Mr. John F. Lorentz, Biology
Mr. Joseph D. Murdoch, Zoology

Consultants:
Professor Emer. Clara H. Bartley
Mr. Lawrence W. Stolte, New Hampshire Fish and Game Dept.

The need for the development of new or previously underutilized food sources is becoming more and more evident as the worldwide protein deficit becomes more critical. Recently, researchers at the University of New Hampshire have begun to explore the feasibility of using selected marine species for commercial mariculture operations in nearby coastal waters. Mariculture, sea farming, is the marine phase of the broader field, aquaculture.

Basic preliminary biological and economic requisites were established and assessed for various marine species to determine their suitability for aquaculture in the Northeast.

Using the criteria of relatively rapid growth, hardiness and adaptability to a wide range of environmental conditions, simplicity of culture methodology and technology, and projected high market potential, the group decided to focus attention on the possibility of culturing the Pacific Coho salmon, *Onchorynchus kisutch*, in local ocean waters. A major factor influencing this decision was the current stocking program for Coho in the Great Bay system being carried on by the New Hampshire Fish and Game Department under the direction of Mr. Lawrence Stolte in an effort to develop a new sport fishery program. The program, initiated in 1967, has been highly successful.

The basic objectives of the sport fishery program and of the mariculture research correspond closely. Both are engaged in the development and establishment of self-sustaining salmonid rearing programs. To combine the technical strengths of both groups, a cooperative research effort was initiated in 1972. The University group is involved primarily in the more basic aspects of the research. Success of both programs depends upon several critical factors such as the establishment of brood stocks of genetically desirable strains, development of optimal diets, disease control programs, and the establishment of functional management practices.

The University-based research program therefore involves investigations concerning: (1) nutrient requirements and diet developments for all stages of salmon culture that will support accelerated growth, early sexual maturity, and high fecundity; (2) the development of disease control programs focused on early detection and prophylactic and therapeutic treatment techniques; (3) the selection for genetically desirable strains of Coho that are adapted to northern New England waters which demonstrate such favorable characteristics as accelerated growth, early returns to spawning grounds, high fecundity, and high viability of progeny; (4) the development of general management techniques for both fresh and salt water phases of production of intensively and extensively reared Coho in Northern New England; and (5) basic economic considerations including a determination of the market potential for commercially reared salmonids in the Northeast, cost-effectiveness studies of basic salmonid rearing techniques and facilities, and economic impact studies of both commercial mariculture operations and a new salmonid sport fishery program in northern New England.

Feeding Time for the Four Month Old Fingerlings Bavendam Photo

Work to date has included planning and development of the program maintaining a close liaison between this group and researchers on the west coast including Dr. Timothy Joyner, Mr. Conrad Mahnken, and Dr. Tony Novotny of the National Marine Fisheries Service Northwest Fisheries Center in Seattle, Washington; Dr. Loren Donaldson of the University of Washington School of Fisheries; and a number of researchers from various parts of the country who are currently involved in similar research.

Preliminary field testing of diets to be used in the saltwater phases of production were started in the spring of 1973 as well as a preliminary evaluation of sites for the location of both fresh and saltwater production facilities. In the early fall of 1973, work began on the development of an autogenous bacterin for immunization against field challenges of vibriosis, a bacterial infection capable of causing mortalities in as much as 98 per cent of a population of confinement-reared salmonids. Concurrently, an experimental freshwater research hatchery-laboratory in Newmarket, New Hampshire with an annual production capability of 60,000 to 70,000 salmon was designed, constructed, and put in operation. Fifty-thousand eyed Coho salmon eggs from the Sandy River Hatchery in Oregon and 25,000 eggs from the University of Washington were obtained and incubated in December. From those eggs approximately sixty thousand fry were hatched and are currently being reared in the Newmarket facility.

Work will continue in 1974 on the development of saltwater rearing systems, disease control experiments, nutrition, and selection for genetically desirable fish.

Sponsored by Sea Grant No. 4-20088 and the Public Service Company of New Hampshire.

Construction Phase—University of New Hampshire—Sea Grant Experimental Salmon Hatchery and Propagation Laboratory

Fish Rearing Station—Coho Salmon Project Bavendam Photo

Coho Salmon Smolt Ready for Salt Water

Human Enteric Viruses in a Waste Recycling Aquaculture System

Co-Principal Investigators:
Professor Theodore G. Metcalf,
Dr. John H. Ryther
Woods Hole Oceanographic Institution

Associate Investigator:
Dr. James M. Vaughn, Woods Hole Oceanographic Institution

Graduate Student:
Mr. Howard A. Fields, PhD program in Microbiology

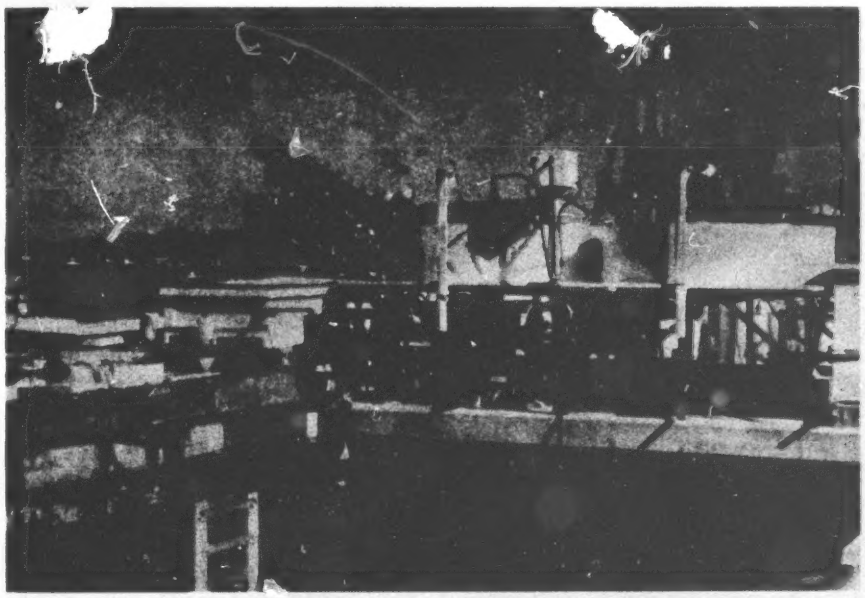
Technician:
Mr. Robert E. Mooney, Microbiology

This research program is being conducted at the Environmental Systems Laboratory at the Woods Hole Oceanographic Institution and at the Jackson Estuarine Laboratory. The program seeks to determine the feasibility and public health aspects of using sewage effluents as a nutrient source in mariculture systems.

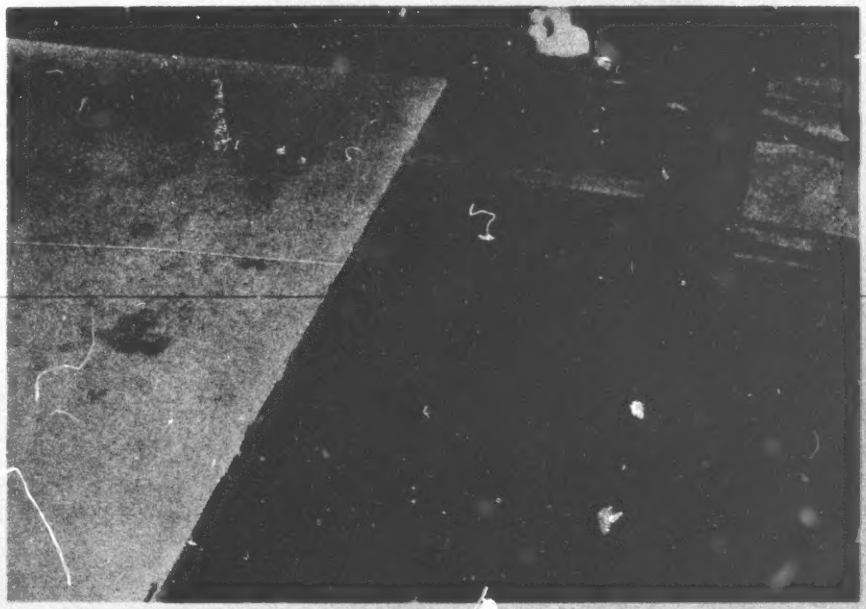
Equal volumes of sewage effluents and seawater are mixed and fed into algal tanks, providing the sole nutrient source for algal growth. Algal masses are fed into shellfish containing tanks, providing a natural food for the growth of oysters, clams, and mussels. Fecal ribbons released from shellfish fall to the bottom of the tanks where detrital feeding seaworms and fin fish remove the formed detritus. Soluble waste products from the shellfish tanks pass into macroscopic algae tanks of Irish moss and sea lettuce where they serve as nutrients promoting algal growth. Abalone imported from California have been found capable of utilizing shellfish soluble waste products as nutrients.

During the process of waste water nutrient usage by marine forms, the water is renovated. Nitrogenous and phosphorous compounds are largely eliminated. This essentially eliminates the eutrophication potential. The survival of enteroviruses in the several stages of the mariculture system currently is being examined.

National Science Foundation—Research Applied to National Needs, Grant No. GI-38976.



Waste Recycling Aquaculture System



Shellfish Culture

Biology and Ecology

Continuation of Field Studies on the Benthic Invertebrate Communities in the New England Offshore Mining Environmental Study (NOMES)

Principal Investigator:
Professor Larry G. Harris

Professional Biologists:
Miss Bonnie Bowen
Mr. Patrick C. Clark
Mr. Andrew McCusker

Graduate Assistants:
Ms. Marianne Dame, PhD Program in Mathematics; Mr. Larry Kelts, Mr. Alan M. Kuzirian, and Mr. Paul Langer, all PhD Program in Zoology; Mr. Frank E. Perron, Master of Science Program in Zoology

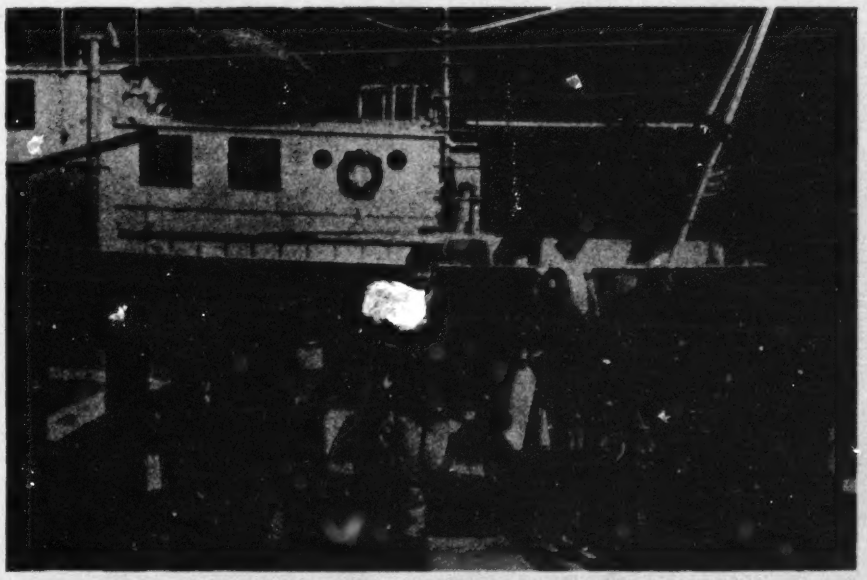
Technicians III:
Mrs. Claudia Foret
Mr. Randolph Goodlett
Miss Beverly Stiles

Technicians II:
Miss Joanne T. Ajdukiewicz
Mrs. Carol Annala
Mr. David F. Hall
Mrs. Kathleen Kremzier
Mrs. Elizabeth Limber
Mrs. Vivian Pelletier
Ms. Virginia Sassomon

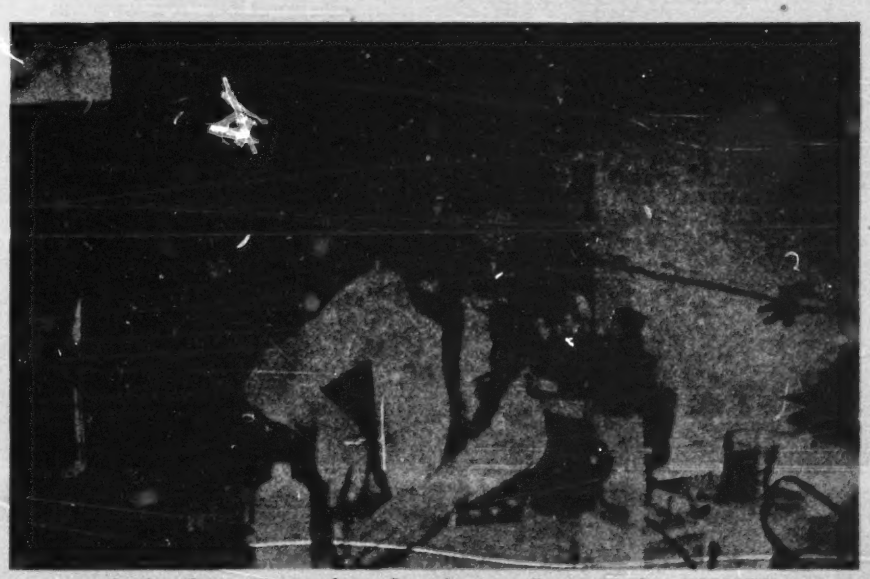
This project was part of a large multi-institutional, multi-disciplinary study of the environmental effects of commercial marine sand and gravel mining. The responsibility of this project was to describe the effects of the indirect disruption by silting, and of the direct impacts of substrate removal, on benthic invertebrate communities. The study was conducted in coordination with the project on benthic floral communities headed by Dr. Arthur C. Mathieson of the Jackson Estuarine Laboratory.

During 1973 the NOMES program, which had been running for over a year, was prematurely terminated because of the lack of a site for dredge spoil disposal. The benthic communities group had been involved in preliminary studies to determine the natural structure of the communities to be impacted by the dredge experiment. After the program was terminated, the primary emphasis was shifted to summarizing over two years of information collected on a monthly regime from 10 to 20 stations on mud, sand, cobble, and rock substrates. This summary will be completed by the end of 1974.

Sponsored by Sea Grant (NOAA) No. 04-3-158-38; Environmental Research Laboratories (NOAA) No. 2-40052; Commonwealth of Massachusetts.



Students Returning from Diving Studies of Boston Harbor (NOMES)



Student Sorting Invertebrate Samples from Boston Harbor (NOMES)

The Distribution of Trace Elements in Marine Bacteria

Principal Investigator:
Professor Galen E. Jones

Associates on the Study:
Dr. Leslie Royle and Mrs. Lindsay Murray, both Department of Oceanography, University of Liverpool, England

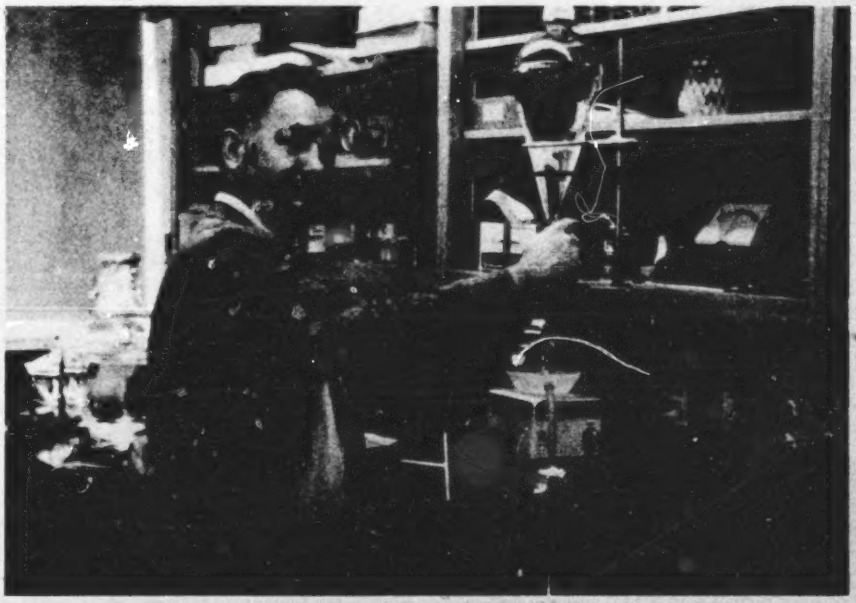
Graduate Students:
Frederick J. Passman and James B. Rake, both PhD students in Microbiology

During the academic year, 1972-73, the principal investigator was on sabbatical leave in the Department of Oceanography, University of Liverpool, Liverpool, England. Professor John P. Riley of that department, one of the world's most famous chemical oceanographers, was the host. The purpose of this investigation was to determine the concentrations of trace elements in marine microorganisms. Factors such as the relative concentration of trace elements in the medium, their interaction with organic matter, their effects on the response of marine bacteria to temperature, pH, salinity, and other environmental parameters, were considered.

The results indicated that bacteria effected much greater concentration factors for trace elements under controlled laboratory conditions from simple well-defined media than from complex enriched media. The metal content of bacterial cells grown in simple media is only slightly less than in complex media, whereas the trace metals available are considerably greater in the complex media. Greatest concentration of individual metal ions by bacterial cells occurs just before an ion reaches a toxic concentration. Toxicity is manifested at the exact concentration where the free metal ions are released from metal binding capacity of the medium.

As trace elements have been implicated in the nutrition, toxicity, and character of marine bacteria, this investigation was conducted to elucidate the functions of metal ions for bacterial activities in the sea. Pollution of the marine environment with metal ions is a product of this industrial age, but the specific metal effects are only beginning to become evident. The death of non-marine bacteria in the sea has been ascribed to the action of heavy metal ions. Abnormal bacterial cell size has resulted from the action of high concentrations of metal ions called megalomorphs. This research has attempted to determine how marine bacteria survive and function in the sea, with special regard to heavy metal ions.

Supported by National Science Foundation Grant GA-34101.



Chemostat Apparatus for Obtaining Steady State Bacterial Population

Microscope Study of Megalomorphs

Drugs from Seaweeds

Principal Investigator:
Professor Miyoshi Ikawa

Associate Investigator:
Professor J. John Uebel

Graduate Students:
Mr. Lawrence J. Buckley and Mr. James D. Sullivan, Jr., PhD Program, Biochemistry; Mr. Victor M. Thomas, Jr., Master of Science Program, Biochemistry.

A number of red and brown algae which occur along the New England Coast have been tested for their ability to inhibit the growth of the green alga *Chlorella pyrenoidosa* and the bacterium *Bacillus subtilis*. The testing was done by placing algal fronds on the surface of agar plates seeded with either organism and observing zones of growth inhibition after an appropriate incubation period.

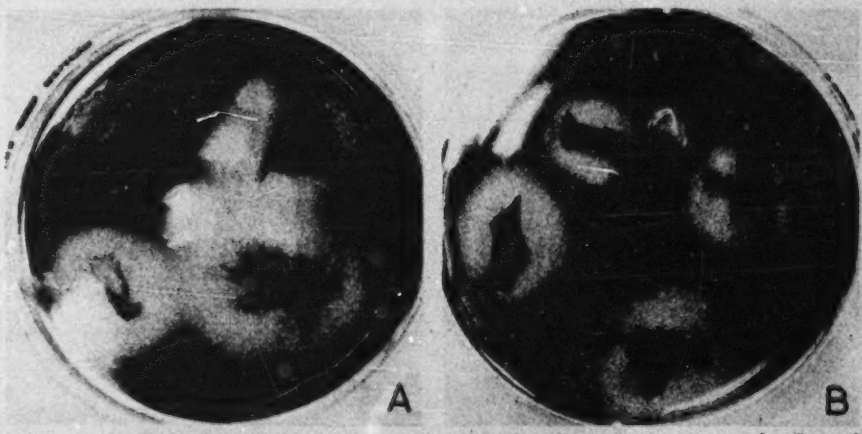
Inhibition of Chlorella pyrenoidosa *growth*

Of the red algae tested, only *Chondrus crispus* and *Euthora cristata* showed strong inhibition of growth, while *Ceramium rubrum, Cystoclonium purpureum, Phycodrys rubens, Phyllophora brodiaei, P. membranifolia, Polysiphonia lanosa, Porphyra umbilicalis, Ptilota serrata,* and *Rhodymenia palmata* showed no toxicity. The brown algae *Agarum cribrosum, Ascophyllum nodosum, Fucus distichus, F. vesiculosus, F. spiralis,* and *Laminaria digitata* were tested and found to be nontoxic The toxicity of *C. crispus* and *E. cristata* was shown to be caused by hydrogen peroxide generated by the action of the enzyme hexose oxidase present in the algae on glucose. The enzyme from *C. crispus* was isolated in pure form by chromatographic procedures. It had a molecular weight of 130,000 as determined by gel filtration and contained approximately 12 gram-atoms of copper per mole. The enzyme is a glycoprotein containing about 70 per cent of a carbohydrate moiety consisting of mostly galactose and xylose. The enzyme oxidizes both glucose and galactose with the production of the corresponding hexonic acid lactone and hydrogen peroxide. It is strongly inhibited by sodium diethyldithiocarbamate.

Inhibition of Bacillus subtilis *growth*

Of 21 species of red algae tested for growth inhibition of *B. subtilis*, only *Ceramium rubrum* showed inhibition zones in excess of 2 cm. from the edge of the frond; *Chondrus crispus, Euthora cristata, Polysiphonia lanosa,* and *Ptilota serata* showed zones of 0.5 to 2.0 cm.; and *Ahnfeltia plicata, Ceramium strictum, Corallina officinalis, Cystoclonium purpureum, Dumontia incrassata, Gigartina stellata, Lomentaria orcadensis, Membranoptera alata, Phycodrys rubens, Phillophora brodiaei, Polysiphonia elongata, P. fibrillosa, P. nigrescens, P. nigra, P. urceolata,* and *Rhodymenia palmata* showed only a trace or no activity. Of eight species of brown algae tested, only *Chordaria flagelliformis* showed a zone of about 1 cm. while *Agarum cribrosum, Ascoplyllum nodosum, Desmarestia aculeata, Fucus vesiculosus, Laminaria digitata, L. saccharina,* and *Sacchoriza dermatodea* showed trace or no activity. The inhibitory substance present in *C. rubrum* was isolated in pure crystalline form and shown to be elemental sulfur by mass spectrometry and thin-layer chromatography. Pure crystalline laboratory sulfur showed the same toxicity to *B. subtilis* as the crystals isolated from the alga. Elemental sulfur analyses performed on a number of red and brown algae showed that *C. rubrum* had 0.008 per cent on a dry weight basis, while the others had less than 0.0005 to 0.0026 per cent. While sulfur strongly inhibited the growth of *B. subtilis*, it did not inhibit the growth of *B. megaterium* or *B. cereus*.

Sponsored by UNH CURF Grant 505 and United States Public Health Service Grant EC-00294.



Effect of the Red Algae Euthora cristata *(A) and* Chondrus crispus *(B) on the Growth of* Chlorella pyrenoidosa. *The Circular White Areas Indicate Zones of Growth Inhibition.*

Immunity in Marine Invertebrates

Principal Investigator:
Professor Thomas G. Pistole

Graduate Students:
Miss Julie L. Britko and Mrs. Rita M. Furman, both Master of Science Program in Microbiology

Studies on the phylogeny of the immune response have been largely restricted to vertebrate species. Because of previous studies on this species, particularly with regard to its exquisite sensitivity to bacterial endotoxin, *Limulus polyphemus*, the horseshoe crab, was chosen as a model for studying immunity. This problem has been approached from several vantage points, in particular: (1) the ability of these animals to respond to injection of bacteria by producing substances analogous to vertebrate antibodies; (2) the bactericidal activity of the serum of these crabs; and (3) the role of the circulating amebocyte in natural defense. The studies to date have shown the presence of a naturally occurring agglutinin to the bacterial genus *Salmonella*. In contrast to classic antibodies this agglutinin does not appear to be inducible by various immunization protocols. The role of this serum agglutinin in immunity at present is unknown.

Supported by two UNH CURF grants, Numbers 511 and 528.

Marine Ciliates (Protozoa, Ciliophora): Morphology and Ecology—Continued Research on Systematics and Autecology of Ciliates in the Vicinity of Adams Point, Particularly Those of Tidal Marshes

Principal Investigator:
Professor Arthur C. Borror

Graduate Students:
Mr. Edwin Martinez, PhD Program, Zoology
Mr. Edward Washburn, Master of Science Program, Zoology

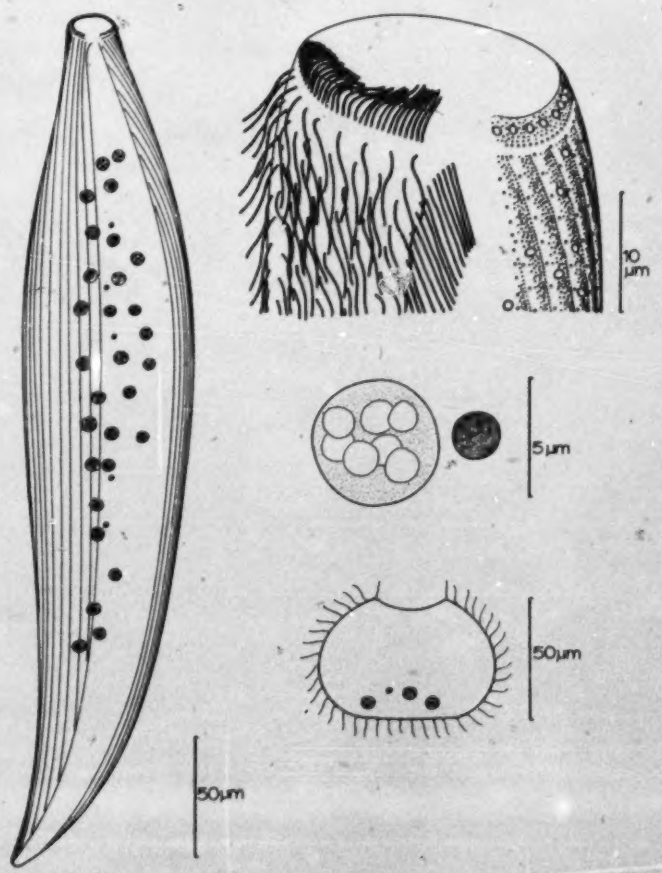
During the 1972-73 school year, four general projects were underway or brought to completion.

Morphogenesis in Euplotes

Mr. Edward Washburn, under direction of Professor Borror, completed a research project describing replication of surface structures in *Euplotes raikovi*, a ciliate occuring in the interstices of marine sands of our coast. He was able to show that despite the aberrant character of the cilia during interphase, the "embryonic" developments during cell division were conservative, resembling sequences seen in more normal members of the genus. His research was published in the November, 1972 issue of the *Journal of Protozoology*.

Systematics in the genus Tracheloraphis

Tracheloraphis is a genus of ciliates that is widespread in the interstices of marine sands worldwide and is commonly encountered. As a group, they are easily recognizable by their extremely elongate, snake-like body form. What appeared to be an undescribed species in the ciliate genus *Tracheloraphis* was discovered by Professor Borror during the fall of 1972. It became apparent that only a thorough revision of the genus and development of a dichotomous key to species in the genus would enable sure identification of the ciliate. The new description of the species, and the key to species of the genus *Tracheloraphis* ap-



Marine Ciliate Tracheloraphis haloetes *Showing Details of Cilia and Cell Contents*

peared in the *Journal of Protozoology* late in 1973.

Ecology of tidal marsh ciliates

Work progressed on the analysis of ecological data obtained previously under projects 18050-FBW and 18080-FBW from the Federal Water Pollution Control Administration. Some of the results of this research had been published during the previous school year.

Protozoology

Mr. Edwin Martinez, a PhD candidate under supervision of Professor Borror, is currently conducting literature search in anticipation of doctoral research in the general field of the effects of temperature upon reproduction and viability in marine ciliates.

Population Studies of Epifaunal and Infaunal Marine Amphipod Crustaceans

Principal Investigator:
Professor Robert A. Croker

Graduate Research Assistants:
Mr. Richard P. Hager and Mr. K. John Scott, PhD candidates in Zoology

Marine amphipod crustaceans are dominant invertebrate animals of rocky and sandy substrata in northern New England. Since 1967, we have studied species characteristics, distribution as related to physical factors, and seasonal structure and dynamics of amphipod-dominated communities of intertidal and near-shore sands.

Amphipod species of sand communities are members of a family found extensively along the Atlantic coast from Canada to Florida. Studies here have resulted in an understanding of the amphipod populations of coastal New Hampshire and Maine in relation to beach exposure, temperature, salinity, sand grain size, organic carbon, total nitrogen, and chlorophyll. Food web data are also available. Studies continue on long-term fluctuations of species composition and abundance at selected coastal habitats, and the monitoring of habitats experiencing environmental upsets.

Rocky shore amphipods show interesting distribution patterns correlated with morphological and behavioral differences. Past and current studies indicate that important generalizations are emerging concerning comparisons with European species and the implications of environmental modifications in Great Bay estuary.

Sponsored by National Science Foundation (Oceanography Section) 18590 and 33743.

Student Sampling Sand Infaunal Populations

Amphiporeia virginiana: *the Dominant Inhabitant of New England Sand Beaches (Length About 4 mm)*

Seaweeds (Attached Marine Algae): Morphology, Systematics, and Ecology

Principal Investigator:
Professor Arthur C. Mathieson

Graduate Students:
Mr. Jan S. Chock, Mr. Ernani Meñez and Mr. Richard A. Niemeck, PhD Program in Botany; Miss Maureen Daly and Mr. Barry Hutchinson, Master of Science Program in Botany

Research Technicians:
Ms. Eleanor Tveter, Mr. Timothy Norall

During the 1972-73 and 1973-74 school years, the following five graduate student research projects were underway.

Ecological study of the fucoid brown alga Fucus spiralis

Mr. Richard Niemeck is conducting a detailed autecological study of the seaweed *Fucus spiralis*. In particular, he is dealing with the ecological factors influencing its vertical and horizontal distribution in the New Hampshire coastal zone. A combination of laboratory and field studies are being conducted.

Ecological-systematic study of the free-living estuarine seaweed Ascophyllum nodosum forma scorpioides

Mr. Jan Chock is studying the seasonal growth and productivity of the plant at a local estuarine site (Cedar Point) in relation to a variety of hydrographic-environmental parameters. Concurrent laboratory studies are being conducted.

Ecology of seaweed communities on a sandy beach at Seabrook, New Hampshire

The seasonal occurrence, distribution and abundance of seaweed populations are being recorded on permanent line transects by Miss Maureen Daly. The transects are located on rock outcrops that are exposed to extreme seasonal fluctuations of sand levels. The occurrence and distribution (with time and space) are being studied by quadrat techniques, in order to relate habitat stability with community structure and diversity.

Subtidal Ecology of Benthic Seaweed Populations in Boston Harbor

The seasonal occurrence and productivity of subtidal seaweed populations were recorded by Mr. Barry Hutchinson at different sites in Boston Harbor. All of the collections were obtained by scuba diving. The standing crop, expressed as dry weight per square meter were recorded. Reproductive trends have also been noted both spatially and temporally. The latter study is an outgrowth of the NOMES Project (New England Offshore Marine Exploration Study).

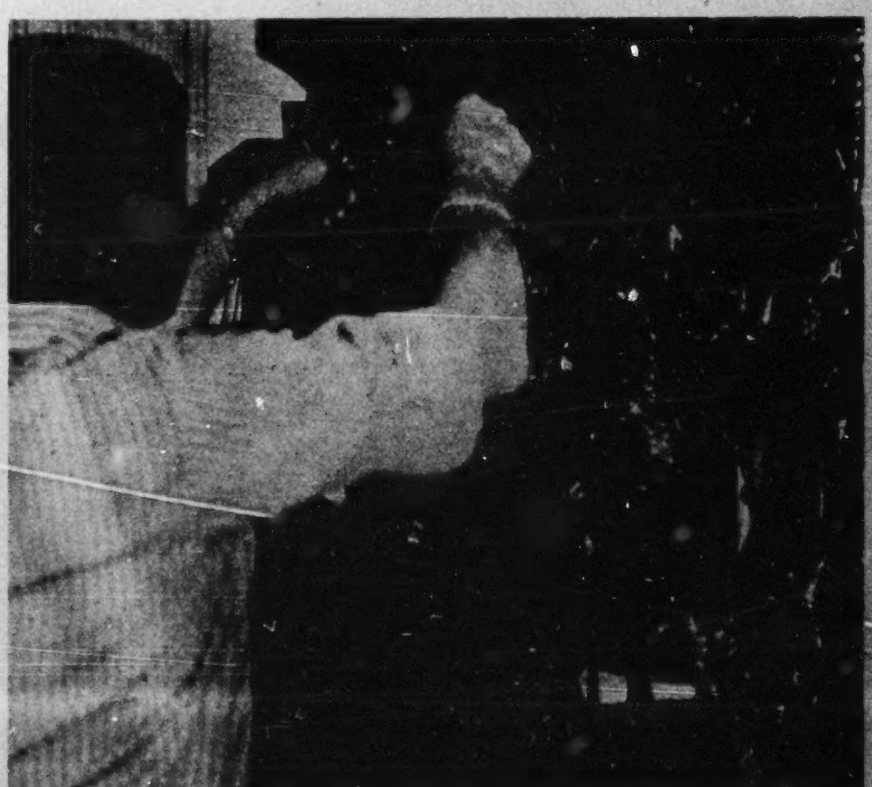
Seasonal Ecology of a Mediterranean Sea Grass Community

This study by Mr. Ernani Meñez is similar to the Boston Harbor studies outlined above, except that it is being conducted in shallow waters (0 to 10 feet) in the Gulf of Tunis in Tunisia. Mr. Meñez is the Director of the Mediterranean Marine Sorting Center and he is completing his doctoral research while in residence at Kherridine, Tunisia. Supporting Agency—Mediterranean Marine Sorting Center and the Smithsonian Institution, Washington, D.C.

Ms. Eleanor Tveter and Mr. Timothy Norall are involved with the three following supported research projects.

Sea Grant—Chondrus *Project*

Ms. Tveter is the research technician on this project, the objectives of which are to obtain a functional



Sorting of Seaweed Samples (Kelps) for Boston Harbor Studies (NOMES)

understanding of colloidal chemistry (i.e. carrageenan) and spore ecology of Irish Moss, *Chondrus crispus*. Carrageenan is a major industrial product derived from red algae; the mainstay of the industry is Irish Moss. Seasonal and spatial variations of per cent carrageenan, proteins, and carbohydrates have been determined, as well as differential gel strengths and viscosities.

Different seaweed properties have been found in the different reproductive types—i.e. sexual versus asexual plants. Detailed studies of spore ecology are now being conducted. The project is directed toward a better propagation and understanding of this economically important seaweed.

Supported by Sea Grant No. 04-3-158-38.

Nutrient studies of the Great Bay Estuary System

Mr. Timothy Norall is the technician of this project in which seasonal and spatial variations of nutrients (nitrogenous and phosphorus) are being recorded in order to evaluate nutrient input into the estuary.

Supporting Agency—Southeastern Regional Commission via New England Regional Commission funds.

NOMES—Boston Harbor Project

Mr. Timothy Norall is presently a part-time research technician on the project. Mr. Hutchinson was formerly associated with the study. The following subprojects are or have been conducted: (1) physiological studies of deep water red algae in which optimal light and temperature requirements of the major deep subtidal seaweeds are being evaluated; (2) seasonal distribution and productivity of deep water plant communities from Boston Harbor.

Support—NOMES Project of NOAA, NG 30-72

A variety of other non-supported research projects are being conducted by Dr. Arthur C. Mathieson concerning: (1) floristic surveys of marine algae in New Hampshire; (2) biological-ecological studies of subtidal algae in northern New England; and (3) environmental "base-line" studies of New Hampshire coastal waters.

Some Chemical and Physical Aspects of Compacted Solid-Waste Disposal in Coastal Waters.

Principal Investigator:
Professor Theodore C. Loder

Faculty Investigators:
Professor Fletcher A. Blanchard
Professor Robert S. Torrest

Visiting Faculty Investigator:
Professor Sheril D. Burton, Brigham Young University

Graduate Students:
Mr. Gerald J. Brand and Mr. Daniel L. Cordell, Master of Science Program in Electrical Engineering; Mr. Peter R. Eppig, Miss Jane S. Fisher, Mr. Erich S. Gundlach, and Mr. Thomas E. Mills, Master of Science Program in Earth Sciences; Mr. Richard W. Savage, Master of Science Program in Chemical Engineering; and Mr. Thomas C. Shevenell, PhD. candidate, Columbia University

Undergraduate Students:
Mr. Robert J. Kostyla, Mr. Alan B. Packard, Mr. Byard W. Mosher, and Mr. John E. St. Andre, Chemistry; Mr. Daniel E. Carr, Mr. Jonathan P. Oakes, and Mr. David M. Wyman, Earth Sciences; Ms. Dana C. Pederson, Microbiology; and Mr. Frank A. Byron, Zoology

Quadrat Studies of Estuarine Seaweed Populations

The basic objective of this research is to improve our understanding of the overall implications of placing compacted solid waste in the marine environment. Because of an increasing demand on land fill sites for solid waste disposal, it has been suggested that the continental shelf area or deep-sea be used as a repository for properly compacted solid waste material until recycling techniques become more widely available.

This research concerns both laboratory and field work. In the laboratory, small bales of shredded solid waste materials were compacted and the void space (60 to 70 per cent) and diffusional properties of the bales measured. The transfer of materials from the bale interior is substantially more rapid (due to the porous nature of the compacted material) than predicted by normal diffusion processes. Other laboratory studies were concerned with estimating the oxygen demand of and the release of trace metals from various solid waste materials placed in seawater.

An *in situ* chemical monitoring system is in the final stages of construction. It is designed to sit on the ocean bottom near bales and measure conductivity, dissolved oxygen, temperature, pH, Eh, sulfide, and ammonia within different bales with data storage on magnetic tape.

In July, 1972, 10 solid waste bales, 5 with and 5 without food wastes, weighing about 90 pounds each and negatively bouyant, were emplaced in 15 meters of water near the Isles of Shoals off the New Hampshire coast. Six concrete cylinders of the same size and with the same covering were also emplaced as biological controls. Since then, the bales have been sampled on a regular basis. Motile and attached organisms are counted around and on each bale by scuba divers. Color photographs are taken to record the physical condition and the extent of encrusting organisms and plants around the bales.

Although some algae were present on the bales soon after emplacement, the major increase in number and species occurred after 8 to 9 months. Heavier growth was found on the waste bales than on the controls. The number of motile organisms (eels, crabs, and lobsters) increased around the bales soon after emplacement, but it was about six months before many motile organisms were found on the bales. Microbiological examination of the sulfur oxidizing bacteria found covering some of the surface of the bales is in progress. Behavioral responses and sublethal effects of solid waste bale eluants on marine invertebrates (crabs) has been started.

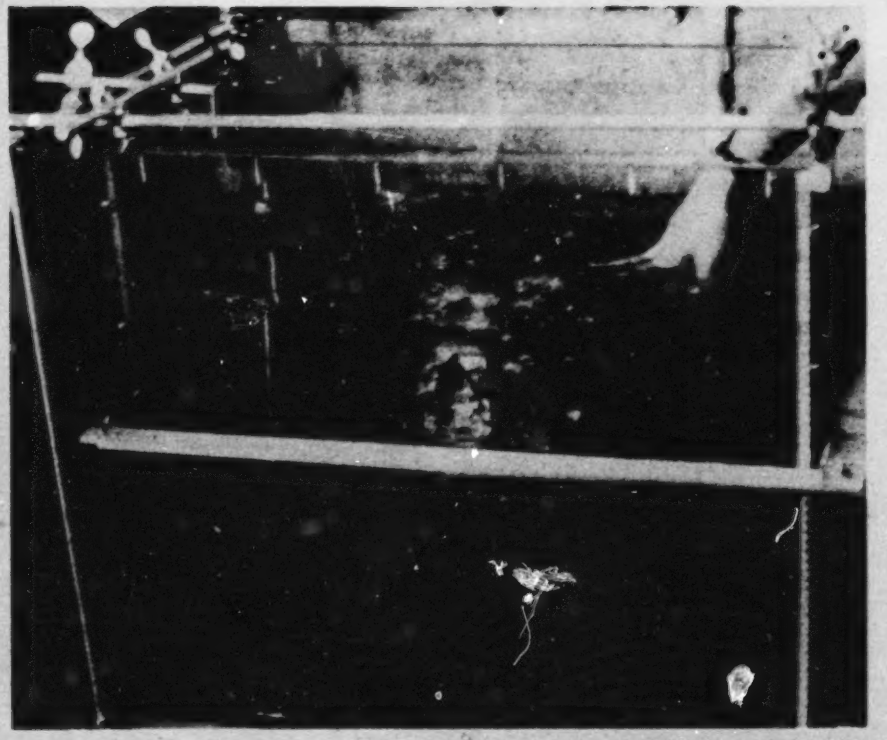
There were definite differences in the chemistry of the food waste and non-food waste bales. The dissolved oxygen content dropped rapidly at first, but then took several months to reach total depletion, at which point sulfides were produced at a greater rate in the food-waste bales. The pH dropped to below 7 initially, then rose to above 9 within a few months for some of the food-waste bales. They then had higher sulfides, ammonia, and phosphate concentrations than the non-food waste bales. A program of analyses of the gases produced by the bales has also been started. As part of this program to understand the environment off our coast where the bales are emplaced, suspended matter and normal hydrographic parameters were sampled for a one year period on a monthly basis. This sampling was done in a large grid pattern off the New Hampshire coast with the Isles of Shoals bale site near the center.

In the summer, several weeks were spent sampling the bales on a daily basis. During this time large plexiglass boxes were placed over entire bales in order to obtain data on whole bale oxygen consumption as well as nutrient release. Divers sampled the interior water of the boxes with large syringes and chemical analyses were run at the Shoals Marine Laboratory.

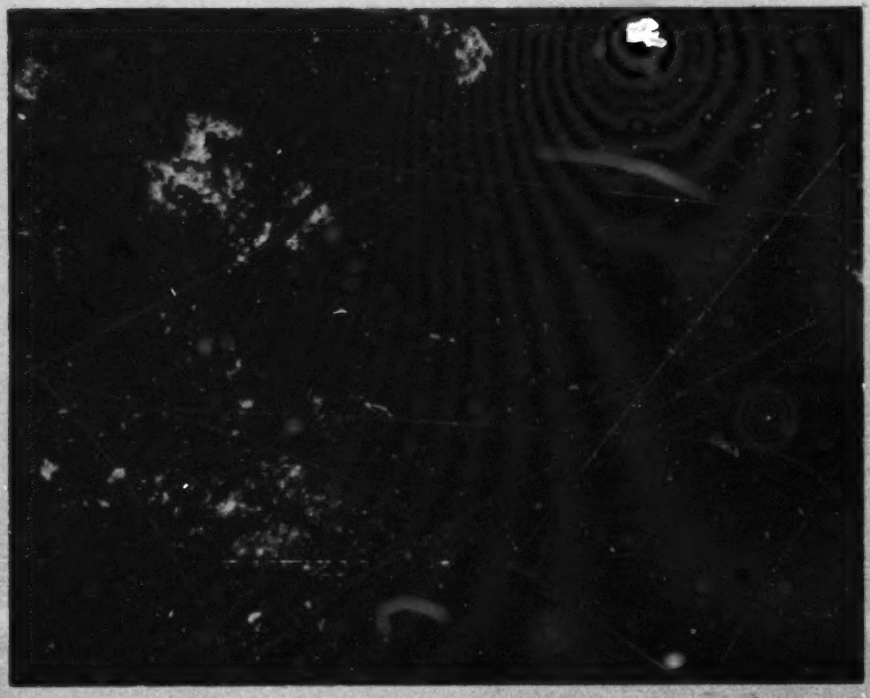
It is planned to continue monitoring these bales for several years to help to achieve a better understanding of the chemical and biological processes that occur during their degradation in the marine environment.

Supported by Sea Grant number 03-4-158-38.

Research Diver Examines a Group of Bales and Records the Number of Organisms on Each Bale at the Isles of Shoals Bale Site



Laboratory Determinations of Diffusional Properties of a Solid-Waste Bale.



A Lobster, Homarus americanus, *Uses a Group of Food Waste Bales for Shelter at the Isles of Shoals Bale Site.*

Structure of the Oxygen Binding Site of Hemerythrin

Principal Investigator:
Professor Gerald L. Klippenstein

Graduate Students:
Mr. Joseph L. Cote, Miss Marjorie M. Mohr, Master of Science Program in Biochemistry; Mr. Frederick Liberatore, PhD Program in Biochemistry

Technician:
Mrs. Susanne B. Ludlam, Biochemistry

The objective of this project is to determine the chemical structure of the oxygen binding site of the oxygen transport protein hemerythrin. This study is being carried out using amino acid sequence analysis techniques in order to identify the amino acids linked to the iron in the oxygen binding site of this protein. Amino acid sequence analyses are being done on hemerythrins from a variety of animal species and from different tissues within particular species of animals.

Sponsored by National Science Foundation Grant No. GB-35610.

Coastal Oceanography

Oceanography of the New Hampshire Coastal Waters

Principal Investigator:
Thomas C. Shevenell, Research Associate, PhD candidate at Columbia University

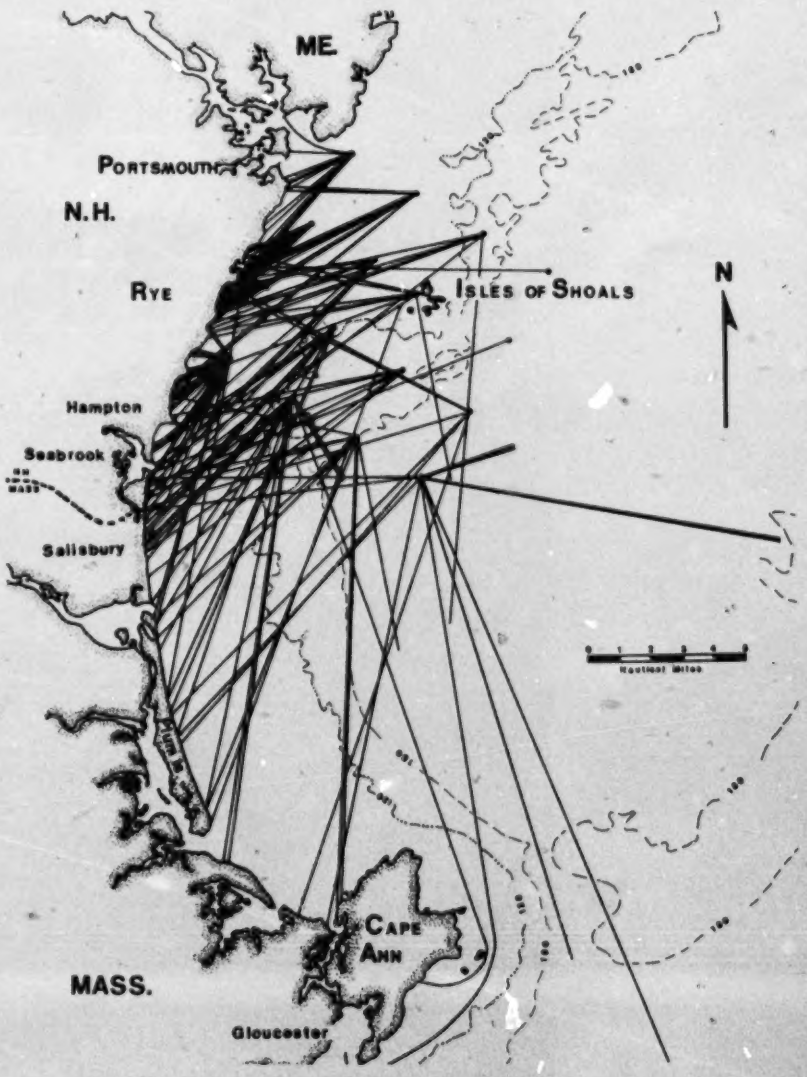
A one-year oceanographic study of the New Hampshire coastal waters was conducted to evaluate the seasonal distribution of physical, chemical, geological, and biological properties. This was a systematic study at a grid of sixteen survey stations and a tidal station in Portsmouth Harbor which were sampled monthly from June, 1972 to June, 1973.

At each survey station both water samples and *in situ* data were collected. The water samples, collected at the surface, 20 meter depth, and 5 meters off the bottom were analyzed for temperature, salinity, nutrients (phosphates, nitrites, and nitrates), trace metals (copper, lead, and cadmium), particulate matter (by volume and weight), particle size distribution (Coulter counter), and plant pigments (chlorophyll a, caratenoids, and phaeophytin). *In situ* light-transmission, conductivity, temperature, and depth measurements were made to the bottom at approximately 3 to 6 meter intervals. Seabed drifters were released on all cruises. A limited number of ballasted drift bottles were also released.

In addition to obtaining base line data to describe the coastal water, a major objective of the project was to study the temporal and spatial changes in the particulate matter distribution as they relate to water mass distribution, sediment and biological sources, and energy environments. The relationships between particulate matter and light transmission are also being studied.

The distribution of particulate matter off the New Hampshire coast fluctuates seasonally in response to changes in basic environmental parameters. Particulate matter is added to the coastal shelf water primarily by biological productivity, resuspension of bottom sediments, and estuarine discharge. Turbidity in the coastal shelf waters is characterized by a surface zone and a near-bottom zone of increased turbidity during times of density stratification in the water column (late spring to early fall). When this density stratification breaks down in the winter an offshore gradient in turbidity is observed. The dispersion of sediment-rich estuarine water into the coastal shelf water is controlled by the density gradient between these two water masses.

Coastal currents off New Hampshire are dominated by a non-tidal, southerly flow parallel to the coast. Associated with this general flow are wind-dependent shoreward and

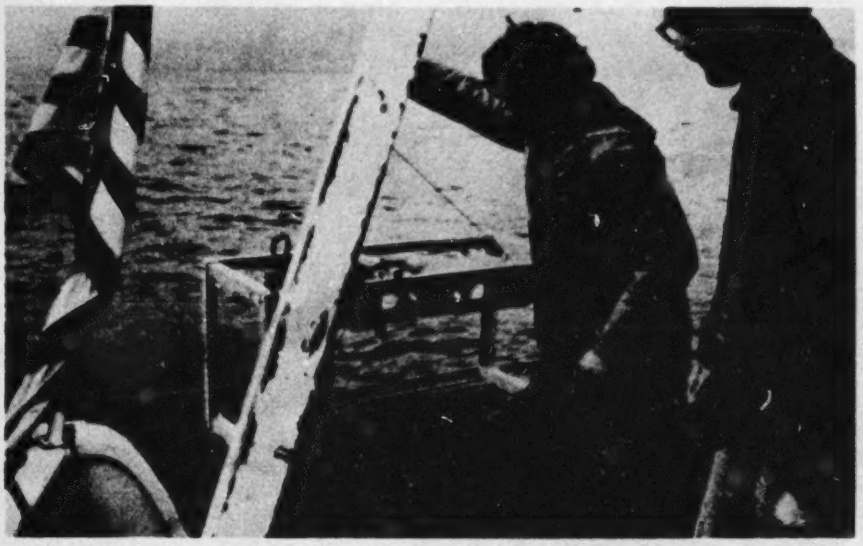


Bottom Drifter Trajectories July 1972—June 1973

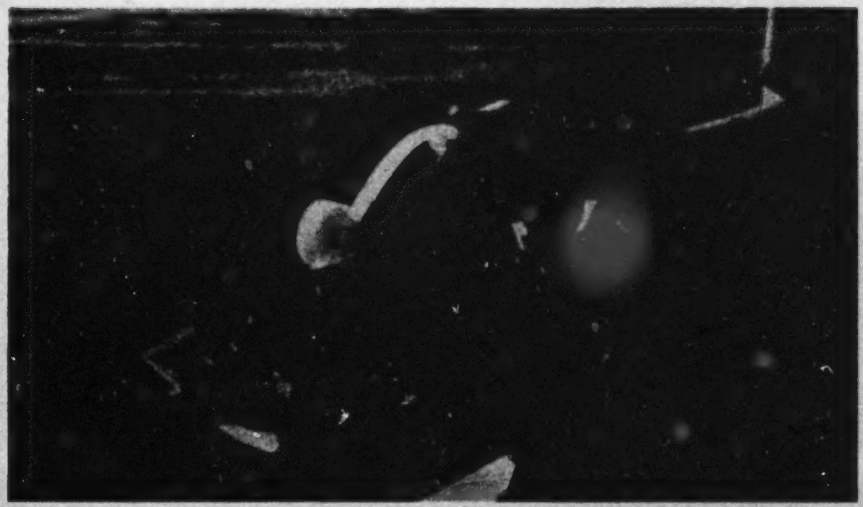
seaward components of current flow. When there is an offshore breeze, upwelling of cooler, deep water near the coast is common. "Northeasters" tend to intensify this southerly flow and also push surface water toward the coast.

At present the particulate matter budget is being studied in detail with respect to particle texture parameters, densities, porosities, and settling velocities. The development of a hydrographic and sediment dispersal model based upon the data collected is in its initial stages.

Supported by Sea Grant No. 04-3-158-38.



In Situ *Instrument Package Used to Obtain Continuous Profiles of Light Transmission, Temperature, and Conductivity in Water Depths to 100 Meters, Aboard the JERE A. CHASE.*



Seabed Drifters Used to Determine the Net Circulation of Water Near the Ocean Bottom. (Note the Spool of Salt to Aid in the Sinking of the Drifter and the Plastic Postal Card Attached to Each Drifter, to be Returned when the Drifter is Found)

Buoy Systems Studies

Wave Measuring Buoy and Coastal Zone Modeling

Co-Principal Investigators:
Professor Godfrey H. Savage
Professor Alden L. Winn

Associate Investigator:
Professor Kerwin C. Stotz

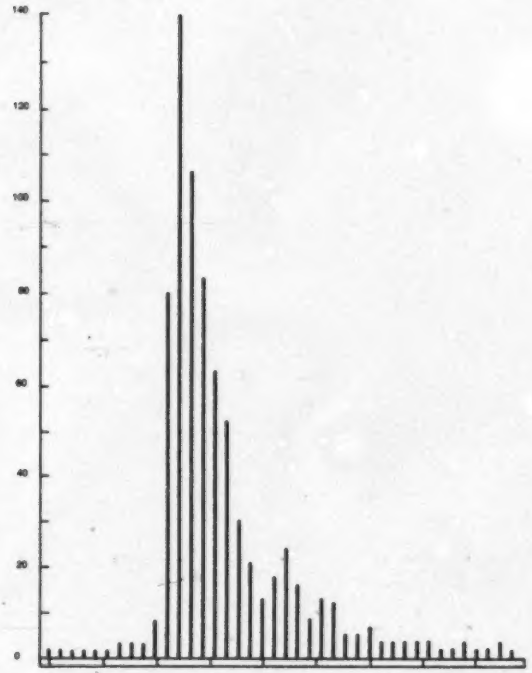
Graduate Students:
Mr. David J. Agerton and Mr. Thomas McGuirk, PhD Program in Engineering; Mr. David O. Libby, Master of Science Program in Mechanical Engineering, Mr. Peter J. Sacchetti, Master of Science Program in Electrical Engineering

Undergraduate Student:
Mr. David E. Dunfee, Mechanical Engineering

Staff and Support Personnel:
Mr. Robert A. Blake, Chief Technician, Mr. Paul E. Lavoie, Diving Safety Officer, Professor D. Allan Waterfield, Volunteer Diver

During the past year, work has progressed on establishing a continuous wave measuring and recording buoy system off the New Hampshire coast using the rubber band tethering and calibrating systems that have been developed at the University of New Hampshire. As has been reported in earlier annual reports of our engineering work, this wave measuring buoy was first successfully installed in the summer of 1972. However, continuing man-created difficulties have interfered with the continuous measurements for which the buoy was designed.

During August and September of 1973, the buoy was in continuous operation and the wave data were recorded at the remote station located on Smuttynose Island in the Isles of Shoals approximately six miles southeast of Portsmouth Harbor. The ac-



An Example of the Wave Spectral Energy Data Developed from the Wave Data Buoy System. Variance Spectra for 6 p.m. September 15, 1973. Max Wave was 7.7 Ft. Significant Wave was 5.1 Ft. (Energy Density Equals Variance Density Times one-half the Density of the Water).

Map Showing Location of Wave Buoy and Smuttynose Island Recording Station. Data Recording Station is Located in an A-Frame House and is Powered by Two 40-Watt Thermoelectric Generators. Wave Measuring Buoy is Approximately 0.5 Miles from Shore in 160 Feet Depth of Water

companying map of the Isles of Shoals shows the location of the wave measuring buoy, the shore cable, and the recording station which is powered by two 40 watt propane-fired thermoelectric generators.

Relying upon the linearity of the stretch of the rubber filaments with which the wave following buoy is moored, and recording the azimuth and bearing of the mooring tether which is constantly under tension, it is possible to obtain the nondirectional wave spectrum for this area with only minimal filtering of the higher frequency wave data caused by the lack of response to waves of periods less than two seconds. These data are recorded on tape in digital form at the remote power station in a suitable format to be placed directly on the IBM 360/50 computer. From these data, wave spectral energy plots have been developed from which the classical analysis using significant waves can be made.

Once again, there have been problems with man-made difficulties causing the buoy to be out of operation during the winter of 1973-74. However, all of the instrumentation is in working order and the buoy will be reinstalled in the spring of 1974 with every expectation that the original objective of recording wave data for a period of at least one year will be achieved during the 1974-75 calendar year.

These data are being developed in conjunction with wave refraction programs including wind and bottom effects that have been described in earlier reports.[1] The refraction program for the Gulf of Maine was used to indicate energy focusing behind the Isles of Shoals during storm conditions for a University Report to the Office of the Governor of New Hampshire as part of a study of the possible impact of a refinery and deep water terminal in the State.[2] Decisions regarding offshore construction of oil facilities and other energy-related proposals will require the development of the kind of data and analysis with which the project is concerned.

Supported by Sea Grant No. 04-3-158-38.

[1] *Annual Report on Progress*, Engineering Design and Analysis Laboratory 1972, p. 10; David E. Thrall, *Development of a Computer Program to Simulate Wind Wave Generation, Refraction, and Shoaling in the Gulf of Maine*, UNH-SG-106, EDAL Report No. 113, March, 1973.

[2] G.H. Savage, E.E. Allmendinger, and D.J. Agerton, *The Impacts of an Oil Refinery Located in Southeastern New Hampshire: A Preliminary Study*, Chapter I—"The Design and Analysis of a New Hampshire Offshore Oil Terminal and Pipeline"; Durham, N.H.: University of New Hampshire, 1974.

Rubber Band Mooring Test for Lightweight Coastal Navigation Buoys

Principal Investigator:
Professor Godfrey H. Savage

Student:
Mr. David S. Agerton, PhD program in Engineering

Staff:
Mr. Robert A. Blake, Chief Technician

Using rubber band mooring technology previously developed at the University of New Hampshire, two test navigation buoys for the United States Coast Guard have been installed at their buoy farm located offshore of New London, Connecticut. Working with researchers and equipment from the United States Coast Guard Research Center in New London, University personnel installed these two test buoys in September, 1973. The purpose was to test the feasibility of using rubber tethers for lightweight aids-to-navigation buoys. Both buoys survived a rigorous four months of weather conditions before they were removed by the Coast Guard for study of any changes in the elastic tether characteristics and to permit further instrumentation of the buoys. At present, the tension changes in one of the buoys is being recorded in an internally recording tension meter, and it is intended that the other buoy telemeter time sequenced data to shore. However, the instrumentation in the second system has not yet been made reliable and neither buoy has been reinstalled since the second one was removed.

This work is continuing under sponsorship by the United States Coast Guard with special emphasis on developing detailed knowledge about the material properties of rubber as they relate to buoy mooring needs.

Sponsored by the United States Coast Guard Research Center, Agency No. 81-1345-73.

Engineering for Buoy Systems—A Statistical Study of Cable Strumming

Principal Investigator:
Professor Robert W. Corell

Graduate Student:
William H. Lenharth, Master of Science Program in Mechanical Engineering

The purpose of this research project is to investigate the phenomena of cable strumming using statistical methods. Designers of deep sea moorings need improved tools to obtain predictions of ocean-current induced mechanical motions of moored cable systems and to predict the intensities of acoustic energy generated by cable strumming. Historically, attempts to predict these frequency-related behaviors

have been based mainly upon the basic differential equations describing the cable system. The literature is rich with such deterministic approaches to analyzing strumming behavior. A comprehensive annotated bibliography on cable strumming has been completed, and will be released in the near future.

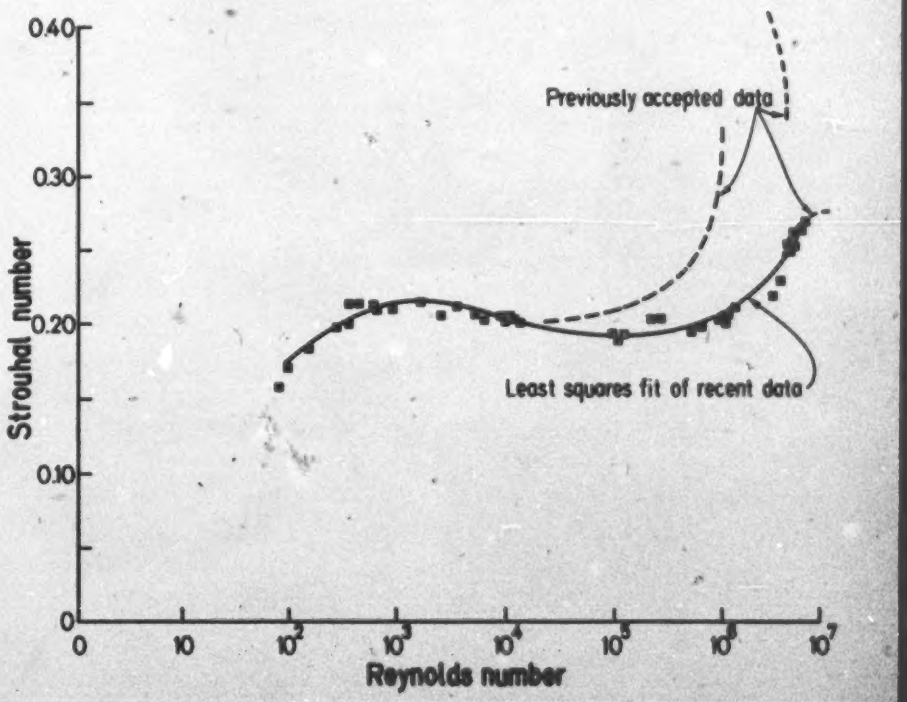
The relationship between Strouhal and Reynolds numbers has been carefully studied. A regression analysis of substantially all published work relating Strouhal numbers to Reynolds numbers has been completed. The regression analysis has provided a new empirical relationship.

Recent work on vortex-induced cable motion, particularly in Russia, reflects important changes in the previously accepted relationship between the Strouhal number and the Reynolds number at Reynolds numbers above 10^4. Such high Reynolds numbers are frequently encountered in the ocean, particularly in buoy moorings. The Strouhal number-Reynolds number relationship can indicate the natural frequency at which vortices are shed, and therefore at which resonance occurs. "Lock-in" occurs over a range equal to approximately ± 25 per cent of the theoretical resonance frequency. Thus cable vibration may be eliminated by using a design strategy which avoids this frequency range. "Lock-in" is the phenomenon which occurs over a range of frequencies near the theoretical reasonance frequency. Over this entire range, the cable will vibrate at its resonant frequency.

Unfortunately, deterministic methods of analysis and design have not met designers' need to predict cable vibration characteristics as a function of design constraints. In general, cable systems are more complex than can be analyzed by the theoretical methods now available. Therefore, this research effort is directed toward applying statistical energy analysis methods to analyzing cable strumming problems. Statistical energy methods have been used extensively in architectural acoustics, spacecraft vibrations, shipboard and submarine vibration, and noise analysis to suggest only a few successful applications.

The initial objective of the project was to obtain such cable vibration characteristics as: statistical distributions of cable velocities and accelerations, distributions of energies in vibrating cables, and energy flows within cable systems. For example, the space averaged velocity squared (V^2), and energy parameter, for a taut-wire mooring was found to be an explicit function of the square of the vortex inducted lift, the correlation length, the loss factor, and the frequency of oscillation. This and other statistical estimates based on energy methods lend themselves to the analysis of complex structures and should provide the designer with "measures of merit" for evaluating the levels of vibration or acoustic noise generated during cable strumming.

Supported by the University of New Hampshire.



Relation Between Strouhal Number and Reynolds Number of Interest in Vortex Induced Cable Motion Showing Recent Empirical Data with a Least Squares Fit and a Curve of Previously Accepted Data.

Man in the Sea

A Saturation Diving Program—Saturation Physiology—Underwater Platform Evaluation

Principal American Personnel:
Professor Godfrey H. Savage,
Professor D. Allan Waterfield, Physical Education, UNH
Mr. Paul Lavoie, EDAL, UNH
Dr. Richard Cooper*, Fisheries Biologist, National Marine Fisheries Service, Boothbay Harbor, Me.
Dr. Donald Beaumariage, Dr. James Miller, Mr. Joseph Vadus, Manned Undersea Science and Technology Office, National Oceanic and Atmospheric Administration
Mr. Ian Koblick, Marine Resources Development Foundation, San Germain, Puerto Rico
Mr. Barrie Walden, Ocean Engineer DSRV, Woods Hole Oceanographic Institution
Professor E.H. Stolworthy, EDAL, UNH
Mr. David J. Agerton, PhD Program in Engineering, UNH

Principal German Personnel:
Herr Gunther Luther, Program Manager, Gesellschaft fur Kernenergieververtung in Schiffbau und Schiffahrt, MBH, (GKSS) Hamburg—Geestacht
Herr Hermann Schmidt, Senior Manager for new products, GKSS
Herr Gerhard Haux, Chief Engineer, Dragerwerke, Lubek
Dr. Heinz Oser, Dr. Anthony Low and Dr. Horst Gragula (saturation blood chemistry) Institut fur Flugmedizin, Bon—Bad Godesberg

During the year 1973 the University's scientists and engineers continued their studies of saturation diving. Missions were conducted at the Puerto Rico International Undersea Laboratory (PRINUL) and at Helgoland in the German Underwater Laboratory (UWL) HELGOLAND.

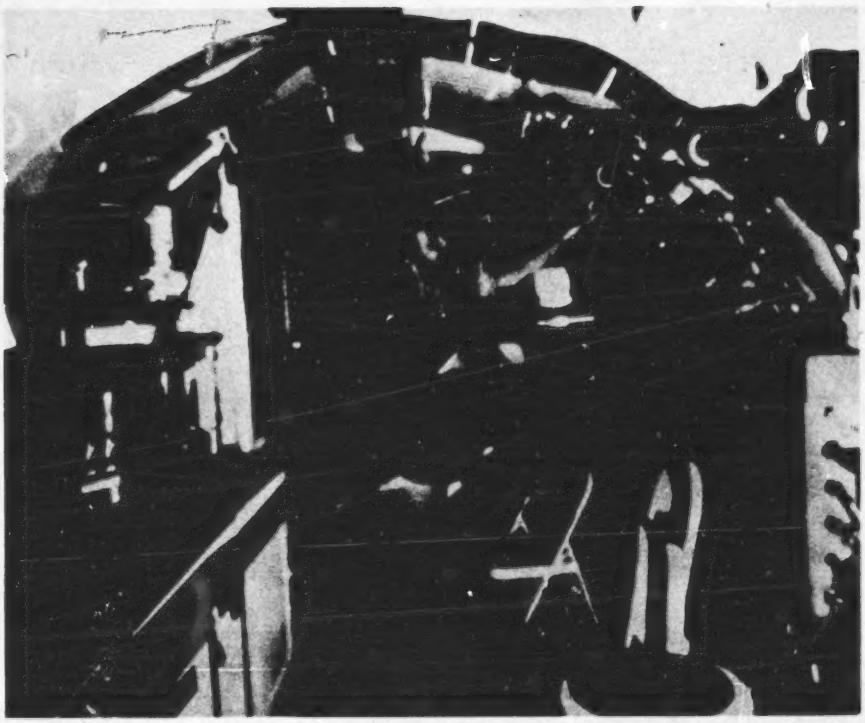
*Now at the National Marine Fisheries Service, Woods Hole, Mass.

PRINUL

The Puerto Rican Underwater Laboratory, La Chalupa, is a towable, self-submerging underwater habitat. The barge-like vessel contains two cylinders, each approximately 8 feet in diameter by 20 feet long. These cylinders are mounted under the deck of the barge and transverse to its centerline. Between them is an entrance area or wet room. Breathing gas cylinders and emergency personnel transfer capsules (PTC) are stored on deck. The laboratory is connected to an unmanned surface support buoy which provides electrical power, high pressure air, and communications. The depth capability of the system is 100 feet and the crew capacity is four diver-scientists.

In April of 1973 UNH personnel joined with other scientists in a 14 day saturation dive 10 miles off the southwestern coast of Puerto Rico in the Mona Passage. Experiments included open sea testing of vertical excursion tables developed by the Environmental Physiology Laboratory of the Union Carbide Technical Center, Tarrytown, New York, for the Manned Undersea Science and Technology (MUS&T) Office of the National Oceanic and Atmospheric Administration (NOAA); evaluation of a diver-to-diver, diver-to-laboratory communication system; color, shape relationships in perception of objects in an underwater environment; and collection of biomedical data: heart rate, skin temperature, and central or core temperature, from free-swimming divers excursing from the underwater laboratory. The unique acoustic biotelemetry equipment utilized in gathering these data was developed at UNH as part of a Sea Grant research program and was described in the EDAL Annual Reports for 1971 and 1972. The biomedical receiver was modified to operate in a hyperbaric atmosphere. At the completion of the PRINUL program, and in preparation for the next mission, significant design changes were made in the telemetry equipment. These changes improved the reliability of the system, made it more diver usable, and for the first time enabled the receiving of the ultrasonic signal within the underwater laboratory itself. In addition to these experiments, the PRINUL mission attained historical significance

American Divers at the 100 Foot Depth—PRINUL (LA CHALUPA)



At Radio—In Control Compartment—LA CHALUPA

HELGOLAND—American Diving Team

by being the first 100 foot saturation dive to utilize a normoxic oxygen-nitrogen breathing gas mixture.

The results of the PRINUL program of particular importance are the verification of the Union Carbide excursion tables and the core temperature profile of a saturated diver. It was found that divers may ascend to within 25 feet of the surface for short periods of time without incurring decompression sickness. Also, it was concluded that a diver saturated at 100 feet, if lost, could surface momentarily, take a compass bearing on the laboratory support buoy, and return to his saturation depth without serious injury.

The biomedical data gathered during the PRINUL mission gave support to the belief held by some saturation divers that the rate of body heat loss while excursing increases with the time into saturation. This finding was further substantiated by the data gathered at UWL HELGOLAND in the North Sea.

UWL HELGOLAND

Since the inception of saturation diving during the early 1960's, programs have been confined primarily to tropical waters. Notable exceptions are EDALHAB in the United States and the German Underwater Laboratory HELGOLAND Operation in the North and Baltic Seas since 1969. To continue with the diver biomedical experimentation as well as investigate the techniques of cold water saturation diving and the suitability of the HELGOLAND Diving System for operation in New England waters, engineers from UNH joined with colleagues from Woods Hole Oceanographic Institution to perform a German-American saturation dive near the island of Helgoland, 60 miles off the coast of Germany in the North Sea.

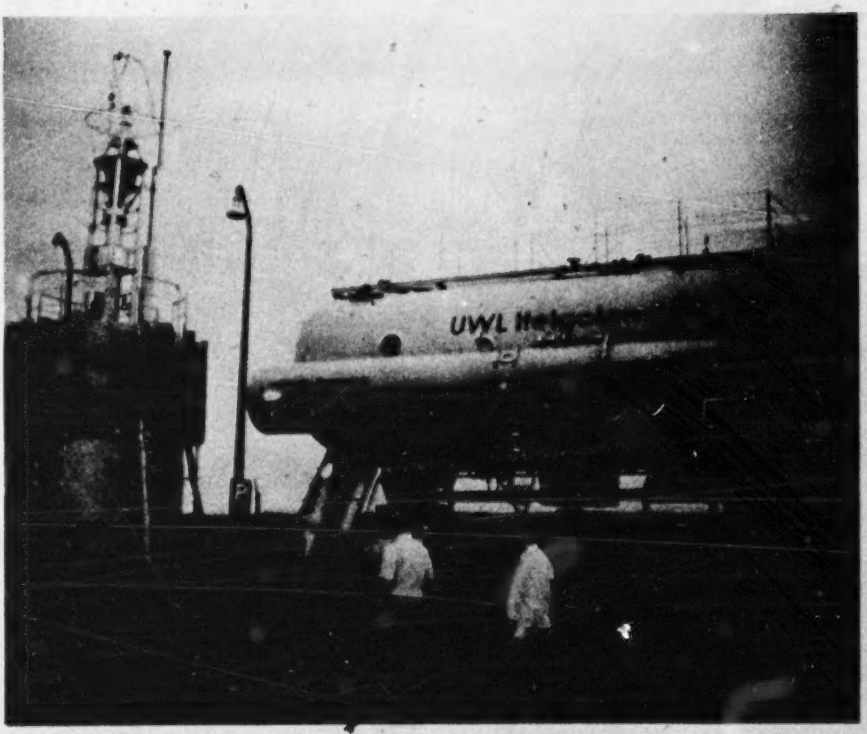
In August of 1973 an engineering team visited the site to gather information regarding UWL HELGOLAND and its systems. The engi-

neering team's interest was twofold: (1) to observe the installation of the UWL and to judge its compatability with U.S. diving procedures; and (2) to make recommendations regarding the suitability of UWL HELGOLAND for use as a saturation habitat in New England waters. The two objectives were pursued concurrently.

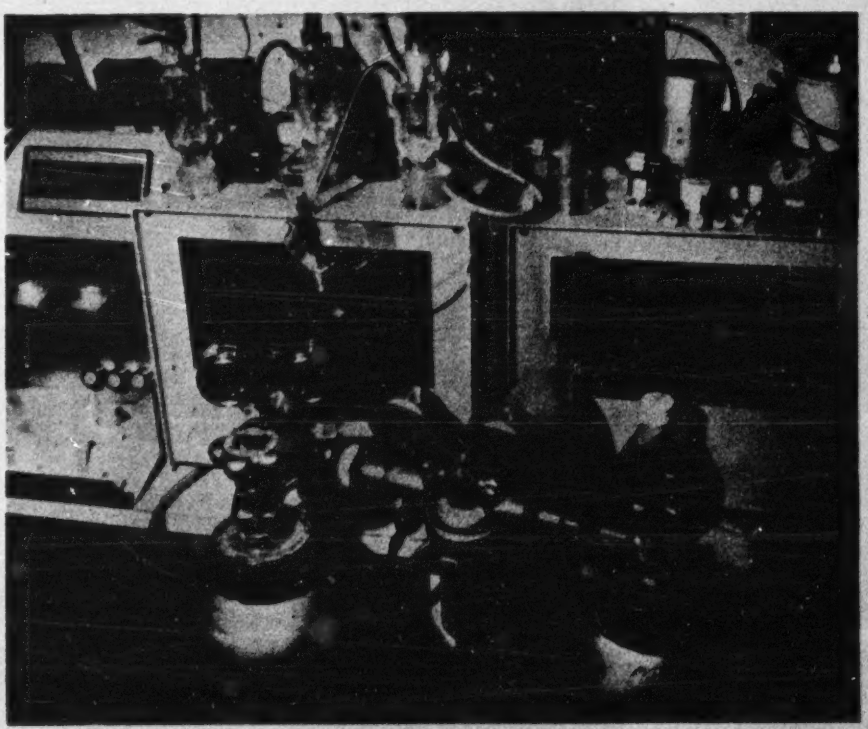
The UWL is a cylindrical structure with ballast tanks used while surface towing and during self-submergence. The main body is 9 meters long by 2½ meters in diameter. A wet room 5 meters long is attached to one end. When in place, the laboratory derives its electrical power from an unmanned energy buoy on the surface. Normal decompression is accomplished inside the habitat. Although the depth capability of the system is 30 meters (100 feet) the proposed dive was to be performed at 23 meters (75 feet) with a breathing gas of normoxic oxygen-nitrogen.

Safety equipment, in design and appearance, was such as to inspire confidence. It included a lift for personnel transfer (PTO), a surface decompression chamber, two emergency rescue chambers, one of which could accommodate a physician as well as the patient, a rescue island, and an underwater igloo.

Upon arrival on the island of Helgoland, the American dive team began training and familiarization with German diving techniques. Three significant differences were found between German and American dive procedures: (1) because of the surface currents and low visibility all diving is done tethered to a surface tender or the UWL; (2) diving is done singly, not in buddy pairs; and (3) all divers must use full face masks with integral regulators. Points (2) and (3) were later modified to conform to American diving policy for the benefit of the American team. Part of the training involved the use of the Drager SMS



UWL HELGOLAND—Energy Buoy at Left. New Wet Room Attaches at Right



Instrumentation for Blood Gas Chemistry inside UWL HELGOLAND

semi-closed mixed gas diving system. It was found to be a superior diving unit and will be considered for future diving programs at UNH.

A German saturation program was under way before and during the training of the American divers. Saturation blood chemistry, psychological adaptation to confined spaces, and *in situ* observation of lobster behavior were the research areas being investigated. Because of the priority of this program and project management conflicts it was not possible to saturate the entire American team at one time. As a compromise, a UNH engineer joined the four German scientists to participate in and evaluate laboratory operation, and to ready the biomedical telemetry equipment. Later the engineer and one German scientist were decompressed and left the UWL. At this time, the rest of the American team went into saturation.

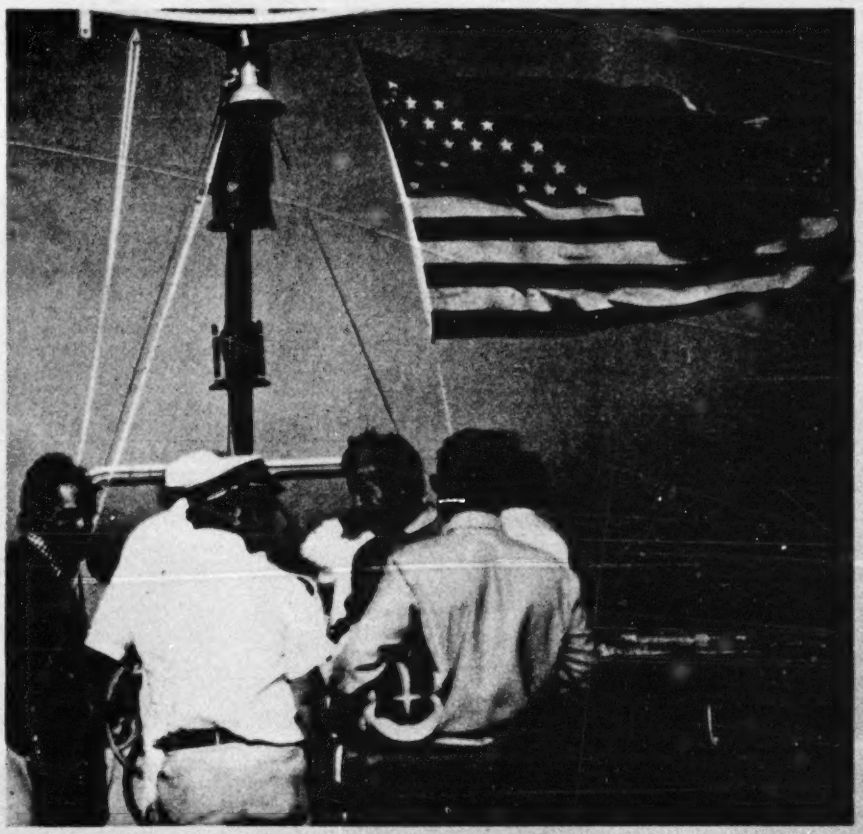
The HELGOLAND program results of interest to UNH scientists and engineers were biomedical data and laboratory evaluation. The modified telemetry system performed extremely well during the mission. Excursions of over an hour were made several times each day and the data gathered on a recorder in the laboratory. Preliminary results, particularly of diver core temperature measurements, correlate extremely well with the PRINUL data. It is intended that the unit be further modified to measure additional parameters such as respiration rate and exhaled carbon dioxide.

It was the intention of the UWL evaluation to assess the ease of installation, judge its compatability with U.S. diving systems, and to make a recommendation regarding the suitability of the laboratory as a saturation diving platform in New England waters. Although the system is ruggedly constructed, installation must be done under calm sea conditions. Internally the UWL was quite comfortable with low humidity and CO_2 levels maintained. With some changes the system can be adapted to mixed gas operation. Scientific and living spaces could be modified to use the available space to better advantage particularly in the wet room or entrance area.

The North Sea weather conditions in the Helgoland area are somewhat similar to those of New England, however, because the island lies in the path of the North Atlantic Current, the water temperature is higher. On the other hand, surface currents in the North Sea can run as high as 2½ knots, a situation rarely encountered in New England waters. In addition, severe storms arise rather quickly. During the saturation of the first American team member, the laboratory and support buoy experienced a storm with 18 to 20 foot waves and 40 knot winds with no difficulty or failure.

The UWL Helgoland system could be used in New England waters to fulfill the need for a regional scientific saturation diving facility to follow Project EDALHAB II at the Isles of Shoals, April 1971. To utilize the UWL effectively here, careful planning of program management, diver training, habitat checkout, and logistical support would be required. A major support ship would be needed for the operation since it is unlikely that saturation dives will be done as close to shore as was the case in Germany. For use in New England waters at greater distances from possible shore bases, considerable thought must be given to the more severe logistic problems.

Supported by NOAA/MUS&T Contract No. 04-3-158-70.



American Diving Team Leaving Island of Helgoland Aboard German River Patrol Boat

Marine Platforms and Controls

A Unique Research Platform—Analysis of Motion Characteristics in a Spar Buoy System

Principal Investigator:
Professor Robert W. Corell

During the past decade there has been increased interest in stable floating platforms, both in the ocean science and technology community and in the offshore petroleum industry. Early work in this field resulted in the construction and very successful utilization of the Research Vessel FLIP of the Scripps Institute of Oceanography. There were several other platforms of similar concept, such as the Navy's SPAR. Armstrong's Aerodrome, proposed during World War II, utilized the spar buoy concept in a design of a large scale stable floating airfield. More recently a Scripps Institute of Oceanography group has been conducting extensive theoretical and experimental design studies for the large-scale stable floating platforms, capable of increasing payloads over those now possible with FLIP. The Japanese floating village and the Hawaiian floating city also plan to use spar-like legs as the supporting elements for the very large stable floating platforms.

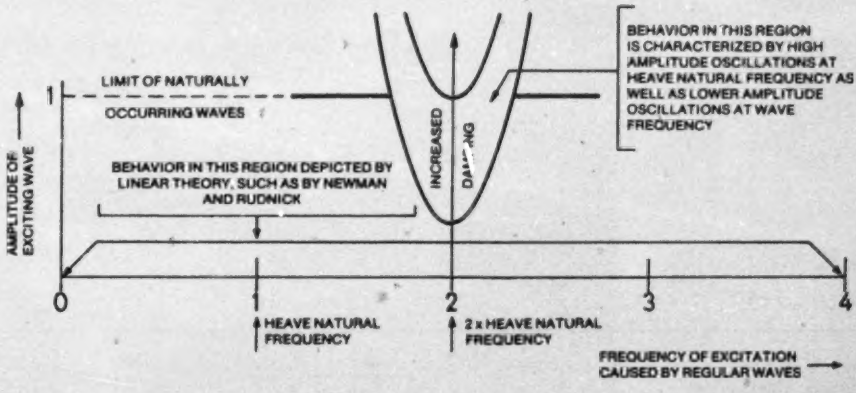
The concept of stable floating spars has been well proven by ten years of operation of FLIP in a wide variety of sea conditions, and by the semisubmersible oil drilling rigs operating throughout the world. However, during experimental studies on large-scale platforms at the Scripps Institute of Oceanography, oscillatory behavior was observed under special conditions which did not correspond to the theory established by Newman[1], Rudnick[2] and others and by experience with FLIP. Spectral analysis of the platform response to regular waves at twice the natural frequency revealed subharmonic and higher harmonic frequency responses. Designers of semisubmersible oil rigs have reported similar "odd" motions.

A theoretical analysis was conducted to determine the origin of these "odd" motions. The predominant phenomenon, excitation at twice the heave natural frequency, was investigated theoretically and experimentally. The analysis predicts dynamic instabilities which "pump" energy from one frequency into the system natural frequency. The behavior results from a system yielding a modified form of the Hill-Mathieu equation[3], which is similar to dynamic stability considerations in elastic systems[4]. The theoretical analysis predicted the "odd" motion behavior observed in the wave tank. A non-linear computer study by Scripps personnel also corroborates the results.

The primary source of the behavior appears to be due to the nonlinear coupling of the vessel motion with the wave pressure field. The phenomenon appears to be sensitive to damping, and is limited to a region of regular wave excitation near twice the natural frequency.

The behavior, while explained to some extent by the heave analysis, needs to be studied further. Both the theory and the model basin studies indicate that substantial amplitudes of oscillation can result from regular wave excitation. However, the effect of confused sea is not fully understood. Experience with FLIP, a single spar, suggests it is not a serious problem. The extent to which this experience can be extended to multi-leg platforms is as yet unanswered.

Supported by Office of Naval Research Grant No. NG-30-72, by the Scripps Institute of Oceanography, and by the University of New Hampshire.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LIMIT OF NATURALLY OCCURRING WAVES
1
BEHAVIOR IN THIS REGION DEPICTED BY LINEAR THEORY, SUCH AS BY NEWMAN AND RUDNICK
INCREASED DAMPING
AMPLITUDE OF EXCITING WAVE
0
1
2
3
4
HEAVE NATURAL FREQUENCY
2 x HEAVE NATURAL FREQUENCY
FREQUENCY OF EXCITATION CAUSED BY REGULAR WAVES

Amplitude of Exciting Wave vs. Frequency of Excitation.

[1]Newman, J.N. *The Motions of a Spar Buoy in Regular Waves.* Report 1499, Washington, D.C.: David Taylor Model Basic, 1963.

[2]Rudnick, P., *Motions of a Large Spar Buoy in Sea Waves*, Journal of Ship Research, Vol. II, No. 4, December, 1967, pp 257-267.

[3]McLachlan, N.W., *Theory and Application of Mathieu Functions*, New York: Dover, 1964.

[4]Bolotin, V.V., *The Dynamics Stability of Elastic Systems*, San Francisco: Holden Day Publishers, 1964.

Seakeeping studies for a Multipurpose Coastal Research Platform

Principal Investigator:
Professor E.E. Allmendinger

Project Consultant:
Professor R.W. Corell

Graduate Student:
Mr. William Swoveland, Master of Science Program in Mechanical Engineering

The University of New Hampshire's at-sea experience and a review of the research requirements of 11 other institutions of the New England Cooperative Coastal Research Facility (NECCRF) have demonstrated the inadequacies of conventional research ships in handling, transporting, and operating many systems, including undersea habitats, submersibles, buoys, drilling and coring equipment, and cable-laying gear. These inadequacies have made obvious the need for a single vehicle capable of safely and effectively supporting a wide spectrum of coastal research projects. It was logical for the University of New Hampshire, through its Engineering Design and Analysis Laboratory (EDAL), to follow its NOAA-sponsored study, Manned Underwater Platforms,[1] by initiating the design of a multipurpose platform. In instigating this project, it was realized that low first-cost and minimal operating expense would be essential to the successful use of the platform by the marine academic community. Consequently, it was decided to base the design on the conversion of a surplus Navy barge having a length of 110 feet, a beam of 35 feet, and a depth of 8 feet. L.R. Closten and Associates, designers of several oceanographic ships and specialized research platforms, were engaged to conduct a study of the proposed conversion. The study resulted in a self-propelled, multipurpose platform. The Closten preliminary design report, submitted to the University in January 1973, serves as the basis for the seakeeping studies now in progress.

The objective of seakeeping studies is to determine, theoretically and experimentally, some of the more important motion characteristics of a barge-shaped platform. This information is necessary to support continuation of the detailed design of the platform and to assist in planning research missions should the platform be acquired.

The procedure associated with the seakeeping studies follows: (1) Structural plans for the barge must be available or must be assumed to provide structural arrangements and scantlings. These are needed to calculate weight, center, and trimming data required to construct both computer and experimental models.

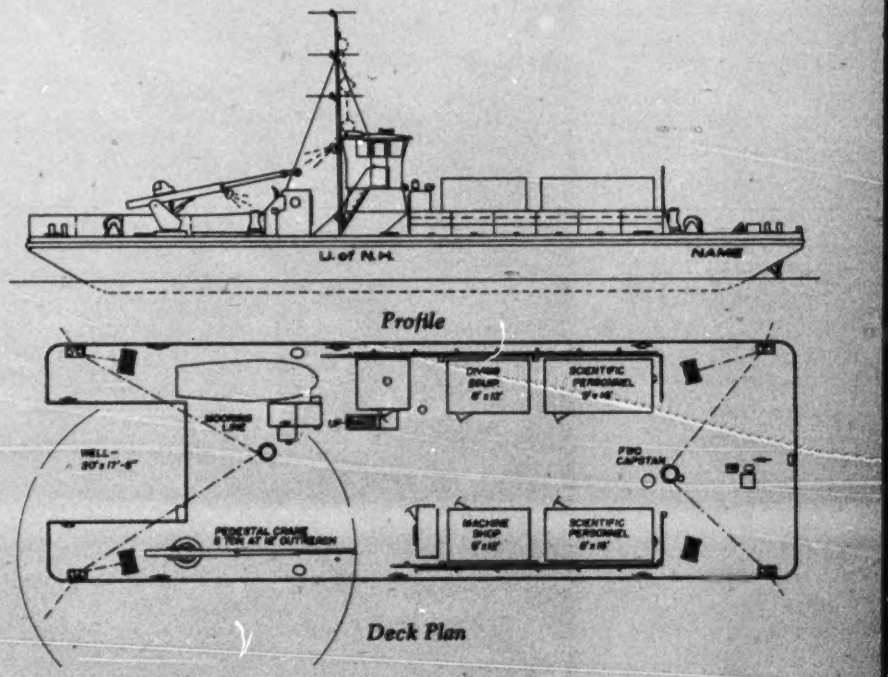
(2) Response amplitude operator (RAO) data are determined as follows utilizing an existing seakeeping computer program: (a) *Ahead Seas* - pitch and heave RAO's for O, 4, and 7 knots forward speed. (b) *Beam seas* - roll, pitch and heave RAO's for 0 knot speed. (c) *Following seas* - pitch and heave RAO's for 0, 4, and 7 knots forward speed. Data will be obtained for "light" and "full-load" drafts. Computer results will provide guidance for conducting experimental seakeeping tests.

(3) Experimental work included is as follows: (a) A scale model of the platform will be built simulating its static and dynamic characteristics. (b) Seakeeping model tests will be conducted and compared with each of the computer studies made.

(4) An analysis of significant response characteristics will be made. This work is intended to produce data of use in predicting the motion of the full-size platform in seaways typical of Northern New England waters.

All activities associated with these seakeeping studies will be conducted at the University of New Hampshire or at the Computer and Ship Model Towing Tank facilities of the Massachusetts Institute of Technology.

Sponsored by Sea Grant No. 04-3-158-38.



[1] *Manned Underwater Platforms*, EDAL Report No. 111, October, 1972.

Submersible Decoupling Control

Principal Investigator:
Professor Charles K. Taft

Associate Investigator:
Professor David E. Limbert

Graduate Student:
Mr. Greg J. Schoenau, PhD Program in Engineering

There has been a recent expanded usage of small submersibles such as Alvin, Dolphin, and Deep Quest for research, rescue, and recovery operations. These Deep Submergence Vehicles (DSV) belong to a new class of submersibles. Characteristic for this group are mission requirements calling for control over the precise spatial orientation and translation of the vehicle in all of the six degrees of freedom. Precise positional navigation is essential for such operations as the search for and recovery of objects from the ocean bottom. With the resulting emphasis on control as opposed to speed the DSV is generally equipped with more thrusters and steering surfaces than the fleet or attack submarine.

It has been observed that even when equipped with sufficient thrusters to maneuver in six degrees of freedom, it may not be possible for the human operator to control the submersible within the prescribed error envelope regardless of the degree of sophistication built into the operator display system. The primary reason for this is that the operator is unable to compensate continuously for the hydrodynamic and inertial cross coupling between the various motions. In other words, although motion in only one degree of freedom is desired, motion in several degrees of freedom may occur with the result that the operator is required to manipulate several inputs simultaneously to eliminate these cross-coupling effects. To perform effectively, the operator should be concerned with only single axis uncoupled control tasks. The purpose of this project was to design a feedback control system to dynamically compensate the system with the primary design objective of having one system input controlling one and only one motion in each degree of freedom. This would enable a more efficient utilization of the operator's time by relieving him of the burden of continuously controlling the DSV to compensate for these interactions.

Decoupling or noninteracting feedback controls strategies were evaluated through computer simulations of the equations of motion of the U.S. Navy's Deep Sea Recovery Vehicle (DSRV). These equations are a complex, coupled, and highly nonlinear set of ordinary time varying differential equations.

To satisfactorily decouple the submersible motions, it was first necessary to develop a theory for decoupling nonlinear systems. During the past year significant advances in the development of this theory were made.[1] The theory was successfully applied to decouple the complete set of equations describing the roll and surge motions of the DSRV. These two motions were selected because cross-coupling is more severe between these two motions than the motions in the other degrees of freedom. The set of equations used included many practical considerations, such as pump dynamics and saturation levels of inputs which were not included in previous models. In addition, a method for extending the results to decouple motion in all six degrees of freedom was outlined.

National Aeronautics and Space Administration, NGR 30-002-056.

Office of Naval Research N00014-67-A-0158-0006.

[1]G.J. Schoenau, and D.E. Limbert, "Decoupling Certain Classes of Nonlinear State Feedback", *Transactions of the Joint Automatic Control Conference*, June, 1973, pp. 65-67.

Wake Steering Shroud

Principal Investigator:
Professor Charles K. Taft,

Associate Investigators:
Professor John A. Wilson
Professor Robert W. Alperi
Professor William Mosberg

Graduate Students:
Mr. Greg J. Schoenau, PhD Program in Engineering, Mr. Joel A. Clark, Mr. Bruce Fellows and Mr. Richard M. Hudson, Master of Science Program in Mechanical Engineering

Undergraduate Students:
Mr. Raymond Gauthier and Mr. Raymond Minardi, Mechanical Engineering.

The wake steering nozzle (WSN) is a new method of steering submersibles. It offers the potential of reducing the number of thrusters as compared with a conventional system while maintaining a comparable order of maneuverability and improving vessel geometric symmetry. The WSN consists of a propeller surrounded by an accelerating-type flow shroud. This shroud or nozzle has the effect of increasing the velocity through the duct enabling it to operate under favorable loading regime.

The use of shrouded propellers as thrusters is not new and has been explored both experimentally and analytically. What is unique about the WSN as proposed by Wozniak, Taft, and Alperi[1] is its ability to develop a steering force as well as an axial thrust. It is based on the fact that a shrouded propeller can be designed which has a pressure distribution downstream of the propeller plane which is lower than ambient pressure. Providing an open slot or control port in the shroud

[1]J.J. Wozniak, C.K. Taft, and R.W. Alperi, "Wake Steering: A New Approach to Propulsion and Control" *Proceedings of the Marine Technology Society*, September, 1972, pp. 681-696.

downstream of the propeller thus allows flow to be induced into the shroud causing a separation of the wake away from that side of the nozzle. This causes an asymmetry in the pressure distribution inside the shroud producing a radial steering force. The ability of the wake steering shroud to generate steering forces at vessel zero forward velocity is an additional advantage over steering surfaces such as rudders.

The objective of the research on the WSN during the past year was to gain an improved understanding of the phenomena to enable an assessment of its potential use in a propulsion-steering system for submersibles. The performance of the WSN was evaluated experimentally at both zero and non-zero forward velocities up to 3 ft./sec.

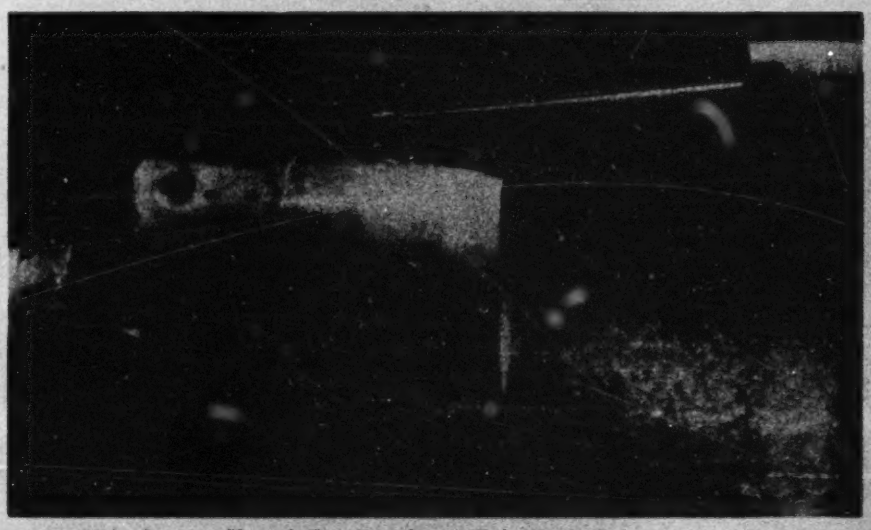
A preliminary series of zero forward velocity of static tests was conducted on a group of shrouds having a wide range of divergence. Many of these shrouds operated unreliably by exhibiting uncontrolled separation of the wake from the inside surface of the shroud producing an erratic radial force. A further series of static tests was then conducted to determine the effects of major parameters of propeller-shroud geometry on reliability and the radial and axial thrusts developed. The parameters varied in the tests were shroud length, shroud divergence, and propeller pitch. A number of propeller-shroud combinations were found which operated reliably. Some of these combinations had radial to axial thrust ratios as high as 0.5.[2]

The shrouds which exhibited high radial to axial thrust ratios and reliable operation during the static tests were selected for further evaluation. These were tested in a water tunnel over a range of forward velocities. The WSN showed a marked increase in radial to axial thrust ratio as forward velocity was increased with little or no decrease in reliability.

A comparison was made between the WSN and more conventional submersible propulsion-steering systems such as the tiltable shroud and ducted thrusters of the U.S. Navy's Deep Sea Recovery Vehicle. The WSN was shown to be more effective as a steering device by virtue of its ability to generate a radial steering force of comparable magnitude throughout the full 360°. However, as a basic thruster the WSN was found to be somewhat less efficient overall. Efforts are continuing to improve the thrusting efficiency of the WSN and other performance aspects such as the ability to proportionally control the steering force.

Office of Naval Research Grant No. N00014-67-A-0158-0006

Wake Steering Shroud, All Port Closed, No Deflection



Wake Steering Shroud, Top Port Open, Wake Deflected away from Port

[2]B.W. Fellows, G.J. Schoenau, and C.K. Taft, "Propellered Fluidic Nozzle for Thrust Vector Propulsion of Submersible Vehicle", To be presented at the Sixth Cranfield Fluidics Conference, March, 1974.

Ocean Engineering—Preparation and Dissemination of Information

Engineering Case Studies for Ocean Engineering—A Report on Two Engineering Cases Prepared for the National Academy of Engineering.

Faculty Advisors:
Professor Godfrey H. Savage
Professor Robert W. Corell
Mr. H.A. O'Neal, Scripps Institution of Oceanography
Professor Karl H. Vesper, School of Business and Department of Mechanical Engineering, University of Washington

Authors:
Mr. Edward R. Kolbe, PhD program in Engineering, MODE-I Study
Mr. Walter Lincoln, Graduate Program in Ocean Engineering, Massachusetts Institute of Technology, North Pacific Study

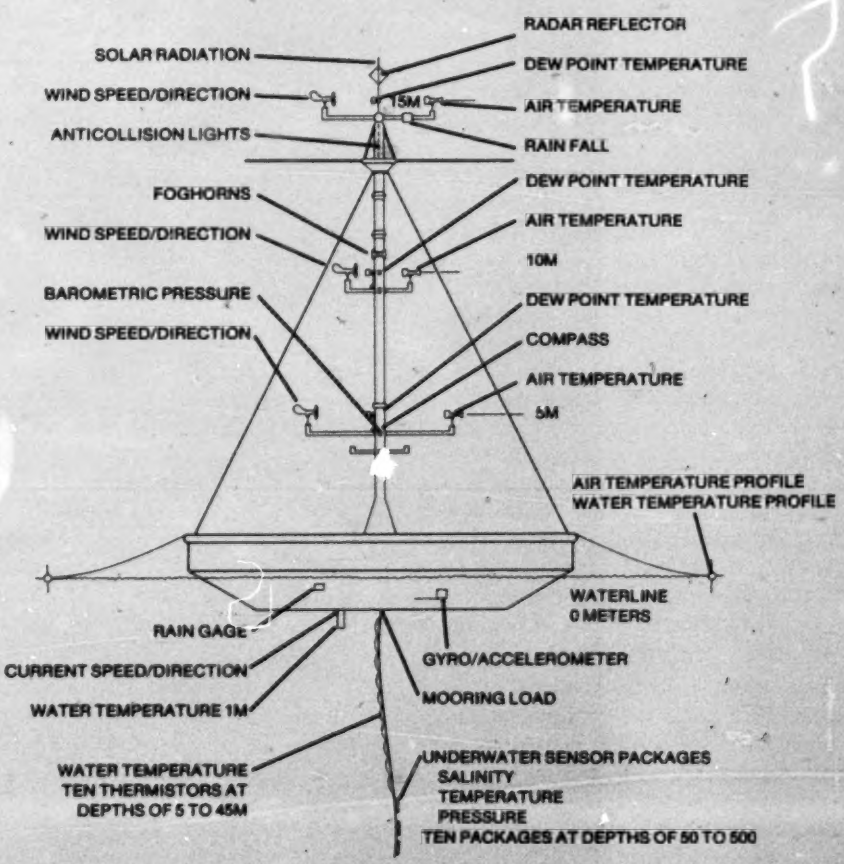
Case studies have long been used as educational tools in business and law, but only recently in engineering. During the past year, a group of faculty and students at the University of New Hampshire, including a student from the Massachusetts Institute of Technology, prepared two major engineering case studies on ocean science and engineering. These cases were written in the style of the Engineering Case Study Method developed at Stanford University and were prepared for the National Academy of Engineering (NAE) Marine Board. They were used at an NAE Buoy Technology Assessment Workshop held in June, 1973. At that workshop, the cases served as documented histories of the development of mooring systems from two large-scale oceanographic experiments, the Mid-Ocean Dynamics Experiment (MODE) and the North Pacific Study. These cases served to focus discussion at the workshop on the many aspects of the state-of-the-art in buoy technology and helped to define future needs and priorities in buoy system research and development.

In addition to these uses, the cases have been submitted to the Engineering Case Library of Stanford University so that they can be available for general use in case study courses and programs. The two cases, one on the Mid-Ocean Dynamics Experiment and the other on the North Pacific Study, are generally related to buoy technology and its relationship to physical oceanography.

MODE-I, An Engineering Case Study of a Moored Ocean Instrument System

MODE-I (Mid-Ocean Dynamics Experiment, Part I) is a project to measure and study certain medium-scale eddies which have been observed in the deep ocean. The case study looks specifically at development of the instrumentation and the mooring systems of MODE.

For years the existence of the medium-scale eddies (around 100 km in diameter) was unknown; so mathematical models of ocean circulation failed to include them. But a 1959 British experiment which used acoustically-followed, free-floating



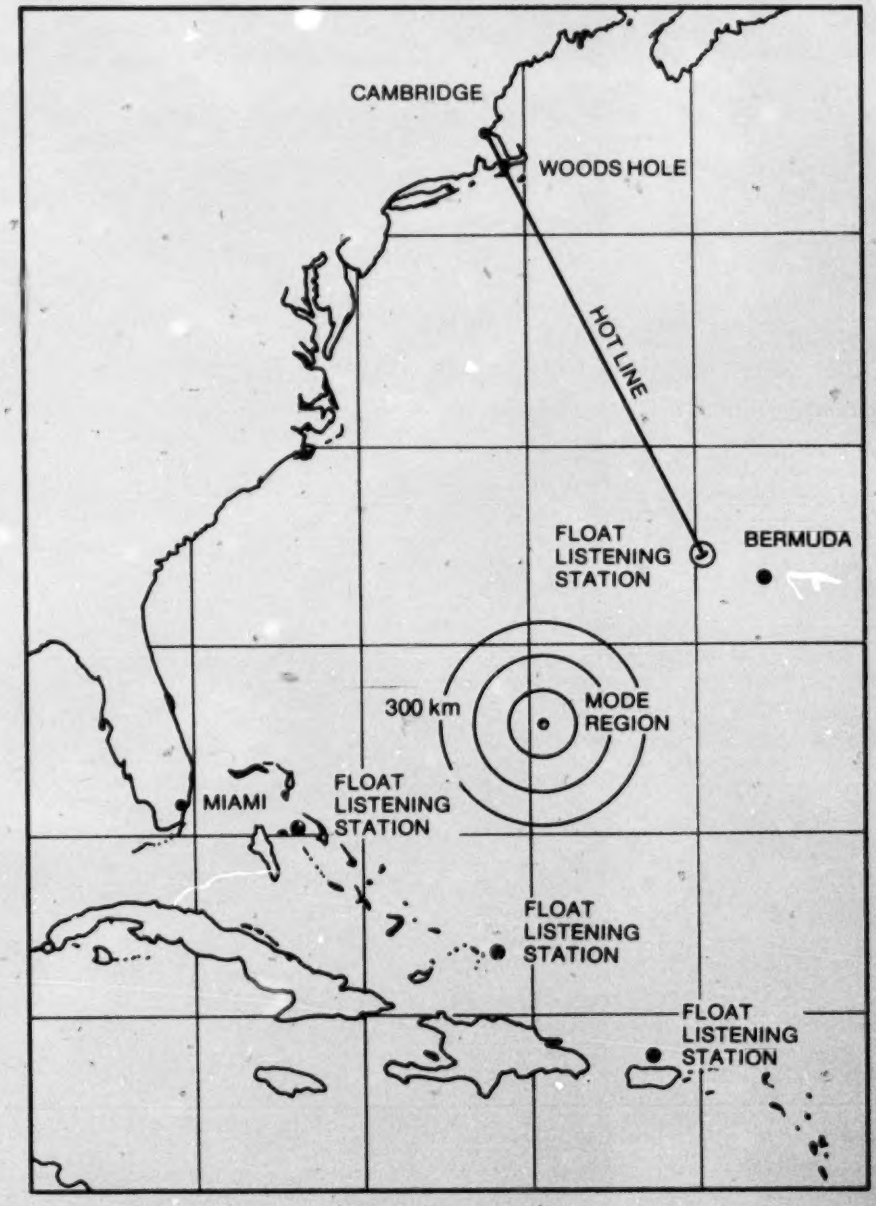
Configuration of Buoys Alpha and Bravo. From Long Distance Telemetry of Environmental Data for the North Pacific Study. By permission R. Devereaux

buoys, showed these energetic swirls to have relatively high velocities. Shortly thereafter a group of scientists met at an international meeting to discuss an experiment which would determine the cause and behavior of these eddies. It was late in the 1960's, however, before the technology of moored instruments in the deep ocean permitted such an experiment to proceed.

Much of the experimentation and development in buoy technology took place at the Woods Hole Oceanographic Institution (WHOI). The past decade saw a remarkable advance in the ability of scientists and engineers to maintain surface and subsurface moorings in deep ocean water. In addition, self-recording current meters and acoustically-triggered anchor release mechanisms were made reliable and long-lasting.

So in 1969, several physical oceanographers again met and planned MODE. The experiment would take place in a typical deep ocean area south of Bermuda. In the spring of 1973 a large array of moorings, covering a 300 kilometer diameter area, was instrumented with over 100 self-recording current meters, 60 temperature/depth recorders, and many bottom-mounted pressure recorders. Four oceanographic vessels participated in the mooring deployment, in the towing of temperature/salinity instruments, and in the launching of other free-floating instruments. The recording of data was scheduled to go on for over five months, with participation of many scientists from many institutions and countries.

The case study tells the story of how this experiment evolved. Specifically, it describes the development of many of the instruments as well as the development of equipment used in the mooring system.



Map of the MODE-I Region

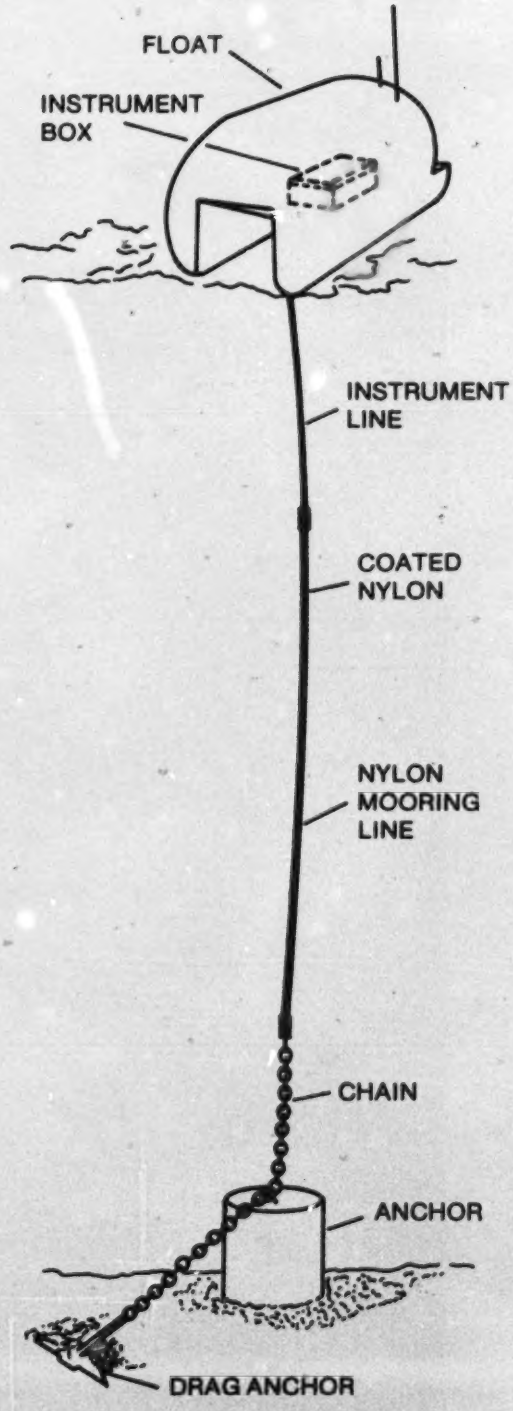
The North Pacific Study; An Engineering Case Study of Ocean Environmental Data Buoys

In 1958 large portions of the Pacific Ocean were observed to be unusually warm for the season. Tropical marine species appeared off the California coast and unusual weather changes occurred throughout Continential United Sates. The Marine Life Research Group (MLRG) at the Scripps Institution of Oceanography, under direction of Professor John Isaacs, along with the Bureau of Commercial Fisheries, was studying the large-scale fluctuations in seawater temperature which affected the general ecology of the California coast.

Earlier, Jerome Namias, then of the U.S. Weather Bureau, worked with Carl-Gustave Rossby, Massachusetts Institute of Technology, in developing the theory of long waves in the jet streams in the upper atmosphere. Namias recognized that a coupling mechanism exists between the sea surface and the upper atmosphere, constituting a closed thermodynamic system. To study ecological systems and the atmospheric phenomena of interest to these two men would require synoptic observations of the environmental parameters over a large area of the ocean.

The North Pacific Study was one of the first successful programs in which environmental data buoys were used as tools to collect data for research in ocean dynamics. Professor John Isaacs initiated the development of buoys capable of collecting and recording ocean and atmospheric data in mid-ocean in the early 1950's and used these buoys in his studies in variations of sea life. The buoy program was successfully used to supply data to other programs, such as research in long waves in the jet stream of the atmosphere and undersea sound propagation.

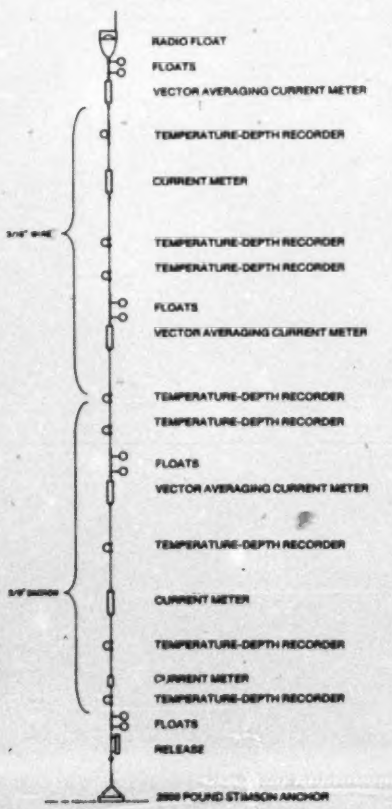
This case study covers the



Taut-Nylon "Bumblebee" Mooring. From "Deep-Moored Instrument Station Design and Performance, 1967-1970". By permission J. Isaacs

development of the first simple plywood and inner tube instrument platform moored to a subsurface buoy located below the effects of wave action. Studies continued through the use of simple skiffs as buoys, subject to capsizing and theft, to the use of non-capsizing buoys of little interest to thieves, such as the BUMBLEBEE and MONSTER buoys. Throughout, concurrent development of instruments, data recording, and data transmissions proceeded; decisions being guided by factors of cost, reliability, and safety. This presentation includes an effort to define the relation between advances in technology and in scientific research.

Funded by the Marine Board of the National Academy of Engineering.



Mooring No. 9-G Typical Subsurface Buoy-Mooring—Instrument Array. Depth 5306 m.

The Sea Grant Marine Advisory Service at the University of New Hampshire

Director:
Bruce A. Miller

One of the primary objectives of the marine advisory effort at the University of New Hampshire throughout this year has been the stimulation of a diversified mariculture program at the University. This effort has resulted in the establishment of ongoing projects in salmon and flounder culture, and the initiation of work on a newly funded Maine-New Hampshire program on the blue mussel. This mussel program, involving the cooperative efforts of the University of New Hampshire, University of Maine, and the Maine Department of Marine Resources, will attempt to establish a commercial blue mussel fishery in New England by surveying the existing blue mussel stock, testing new methods for raft culture, and educating the consumer to accept the blue mussel as a high quality food item. As the level of scientific expertise develops, it is only a matter of time before the first commercial mariculture venture will be started in New Hampshire. In order to avoid political or legal complications associated with such a new venture, a survey of existing laws that might pertain to commercial mariculture has been completed, and is presently being prepared for publication.

The potential for development of a red crab fishery in New Hampshire was studied jointly by the Marine Advisory Service and the New Hampshire Fish and Game Department. Experimental fishing to determine location of populations and effectiveness of gear design was begun by local fishermen, while studies on marketing and promotion were carried out by a team of University economics students. The results of marketing studies on processed crabmeat indicate that a good demand can be easily developed for this quality product, but shortages of fuel and traps forced a temporary postponement of trial fishing before a market could be firmly established.

Studies of sea and fresh water marinas of New Hampshire and their impact on the state's economy were conducted by the Resources Development Center with funds provided by the Marine Trades Association of New Hampshire and the Marine Advisory Services. The resulting report, "The New Hampshire Marina Study 1973," recommended a continuing series of seminars covering bookkeeping, selling, and operation problems. These seminars are being held periodically.

Several Sea Grant student projects have been developed with the assistance of the Marine Advisory Service. The most recent interdisciplinary project now in progress involves students from six departments and focuses on pollution, vegetation, mapping, distribution and abundance of commercially important species, zoning laws, and land use relating to the Great Bay Estuary.

Accelerating development of the marine program at the University of New Hampshire, along with increasing demands for industrial, recreational, and commercial use of the coastal zone, resulted in the need for a statewide vehicle of communication among individuals and agencies working in the marine area. The Marine Advisory Service, cooperating with the Office of Marine Science and Technology, agreed to work jointly on a periodic newsletter that will facilitate up-to-date information exchange among all members of the marine community. The first issue of this newsletter, printed in October, was sent to a selected mailing list for review and suggestions.

The New Hampshire Marine Advisory Service has been actively involved with similar agencies in projects of regional scope, and recently participated in the organizational meeting of the New England Marine Advisory Service (NEMAS) at the New England Center for Continuing Education. The Directors of NEMAS are currently developing plans for a permanent organization, with a full-time coordinator to handle information exchange, conferences and seminars of regional scope, and regional talent sharing.

As marine activity increases in New Hampshire, a broader program will be needed, particularly in the critical area of coastal zone management. Initial development of a long-term advisory program for New Hampshire that will fully meet these needs is progressing. Included in this effort are marine engineering, coastal zone management, and greater facility in exchanges among regional advisory personnel.

Pollution Hazards

Assessment of Potential Public Health Hazards Posed by Galveston Bay Shellfish Subject to Pollution from Domestic Waste Discharges

Co-Principal Investigators:
Professor Theodore G. Metcalf
Visiting Professor of Virology
Baylor College of Medicine and
Sea Grant Scholar, Texas A&M University
Professor Joseph L. Melnick
Chairman, Department of Virology and Epidemiology, Baylor College of Medicine
Professor Craig Wallis
Department of Virology, Baylor College of Medicine

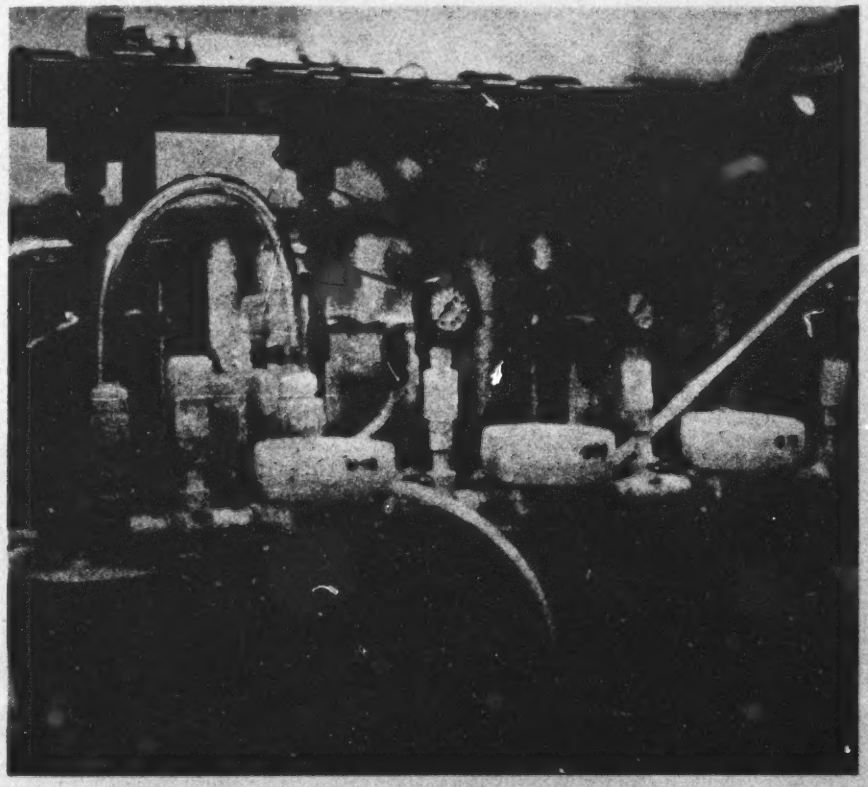
Technicians
Mr. David Reininger and Mr. Robert Price, Department of Virology and Epidemiology
Baylor College of Medicine

Agencies Associated with the Research Program:
Texas Parks and Wildlife Department, Division of Marine Resources
City of Houston Public Health Laboratories

New equipment and techniques were applied to the recovery of enteroviruses from waste treatment plants discharging effluents into the Houston ship channel, from the ship channel itself, and from Galveston Bay. Shellfish in the bay were examined for the presence of enteroviruses. A number of enteroviruses were found and their occurrence quantitated at several collecting stations. These collecting stations were established so as to trace the dissemination of viruses from waste treatment plant point source via the ship channel into bay waters and into shellfish. Parallel examinations of enterovirus and bacterial indices of pollution provided a basis for evaluating the usefulness of direct virus monitoring compared with a bacterial index of pollution for determination of the sanitary qualities of shellfish, shellfish growing waters, and recreational waters. Epidemiological data on types, numbers, distribution, and persistence of viruses in polluted surface waters were obtained.

Simultaneous studies seeking information on the use of equipment and methods for detection and enumeration of adenoviruses were in progress at the Jackson Estuarine Laboratory.

Sponsored by Office of Sea Grant, Texas A&M University, College Station, Texas, and the Environmental Protection Agency.



Virus Concentrator at the Jackson Estuarine Laboratory, UNH

Sea Bottom Resources

The Science and Technology of Utilizing the Bottom Resources of the Continental Shelf

Principal Investigator:
Professor Barbaros Celikkol

Technical Director:
Professor Musa Yildiz

Raytheon Program Manager
Mr. Arthur S. Westneat

Faculty Investigators:
Professor Victor D. Azzi
Professor Robert W. Corell
Professor A. Kiefer Newman
Professor K.U. Sivaprasad
Professor Asim Yildiz

Staff Investigators:
Mr. R.H. Carrier
Mr. Peter M. Vogel

Graduate Students:
Mr. Edward Kolbe, Mr. Gary K. Stewart,* Mr. Karl E. Sundkvist,* Mr. M. Robinson Swift,* and Mr. Halil Tugal, all PhD Program in Engineering; Mr. Ronnal P. Reichard, Master of Science Program in Mechanical Engineering.

This project, initiated in the spring of 1970, has been the first Sea Grant supported university-industry research and development project. Its purpose has been to advance the creation of an effective acoustic technology in order to classify and assess the coastal sea floor and subbottom sediments for both physical and engineering properties. Overall project objectives are: (1) to develop means of acoustically measuring predictive or assessive sea floor parameters that relate to the extraction of resources or to the implantation of structures on the continental shelf; (2) to develop a rapid-analysis, prototype system model for responsible exploitation of the continental shelf which will integrate remote acoustic sensing and ecological technology with the legal and economic implications; (3) to develop a total management system to support and coordinate applied research, conducted jointly by university, industry, and public agencies.

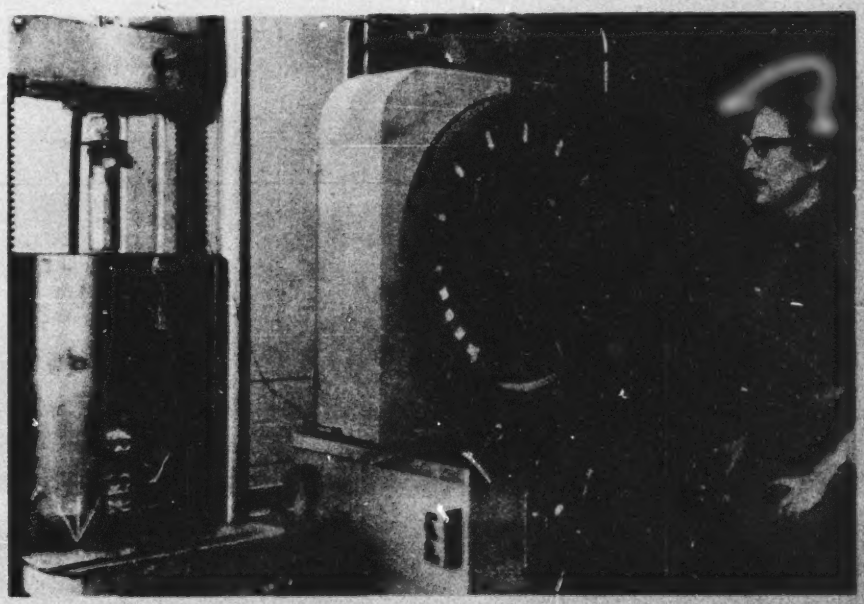
*Also supported by the National Science Foundation.

The three specific technical goals were to develop: (1) technologies to aid in the location, identification, and extraction of coastal mineral deposits, initially coastal sand and gravel deposits; (2) technologies to improve identification of the structrual properties of the coastal ocean bottom needed to design and construct sea floor structures; and (3) an understanding of the influence that exploitation of offshore sedimentary resources may have upon the environment. These broad project obtives and specific technical goals were developed in the context of a five-year research and development project.

Initially, the technical emphasis within this project maintained two themes: first, the development of the basic science and technology for the identification and classification of soil mechanical properties by a combination of remote acoustic surveys and the physical testing of marine soils; and second, the initiation of an environmental-ecological impact study of *in situ* conditions surrounding actual recovery of sand and gravel deposits. The second theme is now a separate project. The major technical areas of study in developing the first theme are: (1) acousto-soil mechanical model development; (2) computer analysis and model corroboration for theoretical analysis; (3) soil mechanics and geomorphology; (4) laboratory activities—analysis of soil samples and propagation of sound through these samples; (5) signal processing of experimental acoustic data; and (6) the development of exploration systems and technology.

Acousto-soil Mechanical Model Development

In the early phases of the project it was recognized that the widely-used ray theory approach to the acoustic-soil mechanical interactions, associated with the remote sensing of sea floor parameters, would not be likely to yield increased insights into the basic pro-



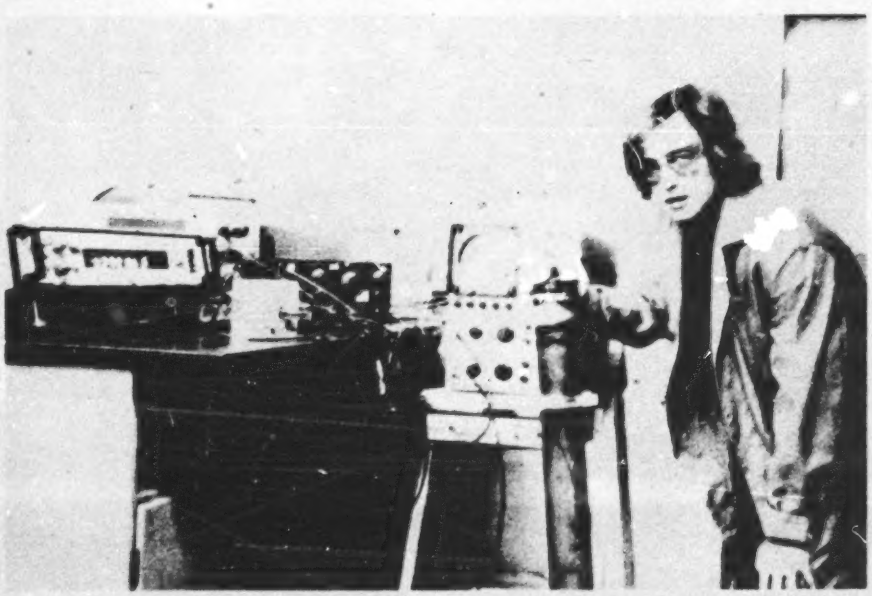
Testing the Marine Penetrometer

cesses. A theory which is more sensitive to subbottom parameters was necessary. A field/theoretical approach was pursued early in the project because the all-important physical phenomenology could be included in the analysis. When sensitive interrelationships of acoustic and physical parameters in a multi-layered environment are sought, the analysis must not be oversimplified. The emphasis during the first years has been, therefore, to overcome the mathematical complexities, starting with simple models which have been increased step by step in complexity until an adequate representation of the physical world has been achieved.

The models, based on the physical considerations, have been developed for the full range of equivalent angles of incidence from normal incidence to highly oblique angles. The results obtained are for water depths of 50 to 600 feet and for frequencies of 3 to 20kHz. The results are for the acoustic response created by a steady-state, point source in a semi-infinite liquid overlying a viscoelastic halfspace, with n-layers of differing properties. Formal solution of an n-layer liquid viscoelastic system has been developed and Green's function formalism for an arbitrary layer expressed.

Computer Analysis and Model Corroboration for Theoretical Analysis

Extensive computer studies have been conducted to begin an understanding of the implications of the Green's function formulation of the single layer model. Computer programs are now operational to accomplish the following: (1) provide an "exact" solution by numerical techniques to the closed-form integral formulation to the single-layer viscoelastic model; (2) to compare the "exact" solution with classical ray theory predictions for the same geometries and conditions, and with other methods of solution which might be potentially more efficient in computer time; and (3) to provide theoretical insight into model behavior, so as to develop predictors and classifiers that would be effective in experimental and operational systems to locate, identify, and classify marine subbottom materials.



Laboratory Measurements of Shear and Compressional Velocities in Marine Sediments

The computer work has resulted in other technical progress, such as a general theory for compensating acoustic transducers.

Soil Mechanics and Geomorphology

A comprehensive effort has been made to integrate the fundamental soil mechanical property descriptors, such as Lamé constants, into the analytical model development activities. Additionally, the remainder of the activity in this area has been related to experimental soils data acquisition: (1) classification of marine sediments, and (2) engineering properties data.

Classification Data—During the first year of the project, marine core data were obtained by a coring system previously developed under Sea Grant funding at UNH. Data, both soil mechanical and geomorphological, were obtained from cores taken at acoustically-probed sites. Cores from two locations were particularly significant in that oblique acoustic experiments were made concurrently: (1) Core 59 (Mackerel Cove) was most uniform in acoustic reflection as a function of core section depth; (2) Core 58 (Price's Neck) was second best in acoustic uniformity as a function of core section depth, and Core 60 (also Price's Neck) was the least uniform.

The measure of core acoustical uniformity as a function of core section depth was computed as follows. The normal-incidence acoustic reflection coefficient was computed from the soil laboratory data for each one foot core section as a function of the depth of that core section; then the variation of this coefficient as a function of core section depth was tabulated.

Essential to the classification problem is obtaining longitudinal and transverse (i.e. compressional and shear) wave velocities. Prototype instruments were designed and con-

structed to measure both of these soil velocity parameters. Measurements made with the laboratory prototype correlate well with published data in the literature. While they have been used only on core samples, the principles employed in the laboratory models could be used in *in situ* systems. A shear wave velocimeter has important implications to the present research activity and an *in situ* model is being developed.

A student engineering design project team undertook the design and construction of an underwater dynamic cone penetrometer. This cone penetrometer is a land or marine device which can give indications of soil engineering properties such as internal friction angle, relative density, and bearing strength. The prototype penetrometer will be used to study the correlation between physical and acoustic soil properties and penetrometer data. A theoretical analysis of the cone-soil interaction is now under way which should help to identify the significant parameters essential to experimentally evaluating bearing strengths.

Laboratory Activities

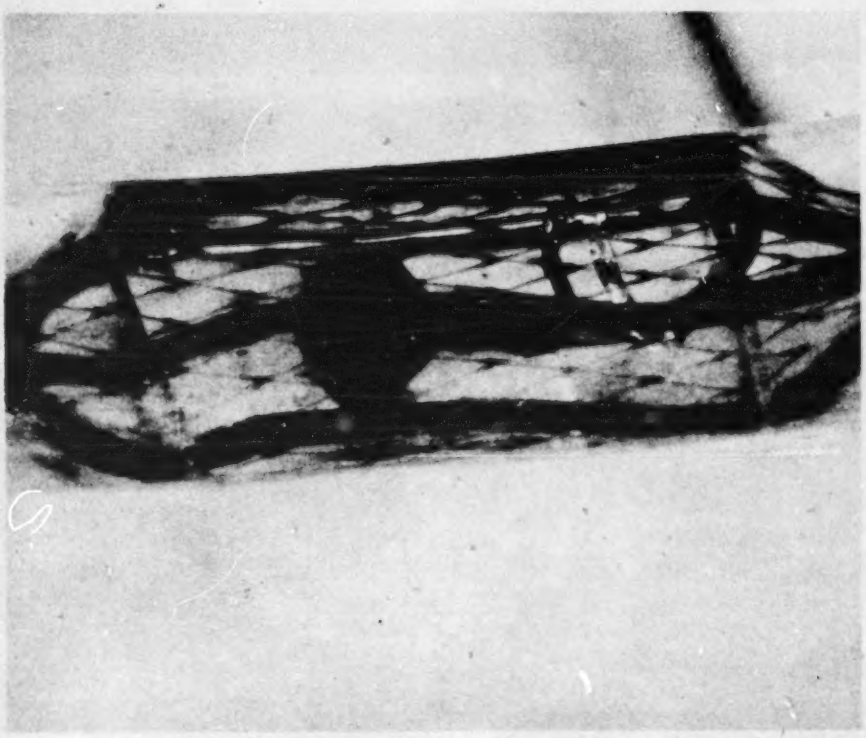
In addition to routine soil analysis conducted during the second and third years of the project, laboratory instrumentation was developed to measure compressional and shear wave speeds of sound in core samples and laboratory formulated sediments.

A typical laboratory experiment is to deposit sediment of given grain size distribution into a specially designed tank. Then the compressional and shear wave propagation properties are measured and the geotechnical properties monitored as the soil dries and the porosity changes.

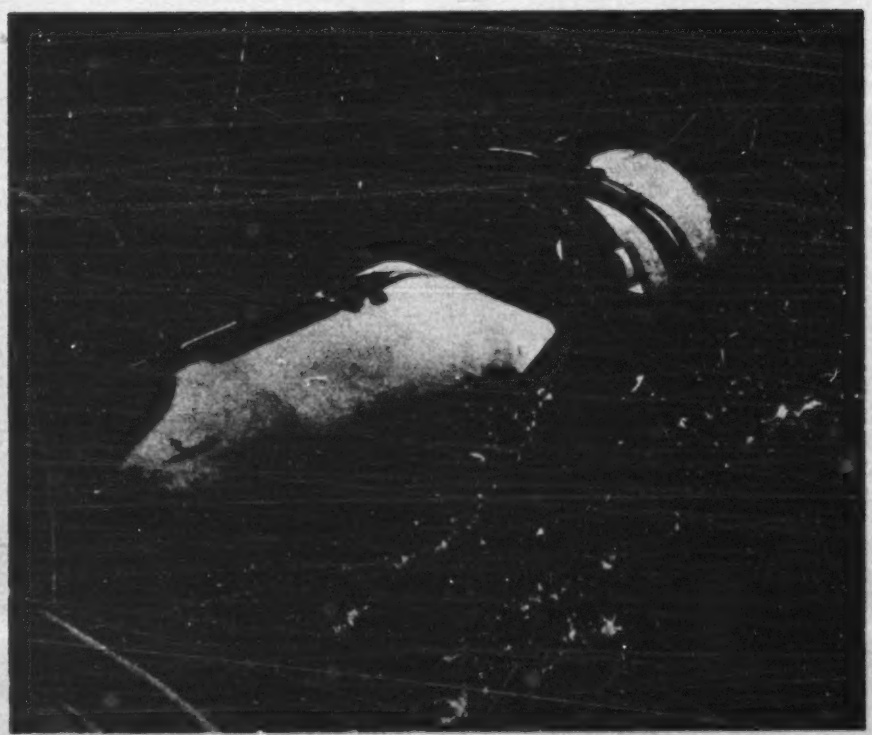
The shear wave velocity meter mentioned earlier radiates a shear wave in two antennas through two unequal path lengths in the soil. In addition to the ease of finding the attenuation, this arrangement facili-

Studying the Computer Output of the Digitized Signal.

Project Students in a Theoretical Discussion



An Element of the Transducer Array



"Fish" Towing Transducer Array

tates precise measurement of wave speed without considering the rise time of the transducers. Knowledge of sound speed, when coupled with the knowledge about the density of a soil, gives information on the dynamic structural constants of the soil under study.

Field Activities

Substantial analysis of the first year's data resulted in a guide to subsequent field activities and data collection. The analyses suggested that: (1) spatial variability of the sediments in the Narragansett Bay test areas is very high, contributing to high scatter in the resulting acoustic measurements; (2) ship motion contributes significantly to the variability in acoustic signatures from marine sediments. Sensor beam pattern effects resulting from yaw and pitch motions, and background noise also contribute to the increase in the spatial variability; (3) normal incidence measurements should be augmented with oblique scattering techniques, otherwise they essentially repeat published reflection coefficient data without enhancing the understanding. To generate a predictive tool requires precise examination, physically and acoustically, of highly specific sites. Thus, the data collection of this project, was based upon a general policy of examining a few carefully chosen sites in substantial detail.

The second year's data collection included additional coring to establish the horizontal variability in the sediments, a stabilized bottom-mounted array to remove ship motion, and a series of experiments to provide oblique measurements in addition to the normal array configuration. Subsequent analysis of this data has yielded three distinct conclusions regarding sources of variability in quantitative measurements of bottom-reflected sound: (1) significant reduction in the amount of scatter exhibited by acoustic data

can be effected by using acoustic measuring systems possessing increased spatial stability. Such a system should include an automatic acoustic path-length compensation technique to correct for residual spatial variabilities caused by movements in the monitoring geometrics; (2) a further increase in data consistency can be achieved through the incorporation of narrow-band analysis techniques as opposed to a total energy analysis approach; and (3) a significant increase in the confidence of these measurements can be attained by calculation of acoustic indices based upon ensemble averaging of an extended time series of pulse return data.

Signal Processing of Experimental Acoustic Data

Extensive acoustic and physical data have been acquired as a part of this project. The details of the initial phases of several experimental data acquisition cruises are summarized below: (1) An extensive data bank of acoustic signatures for a variety of known sedimentary types was obtained employing a range of source center frequencies from 3 to 16 kHz. Acoustic samplings were matched with core data to search for acoustical indicators of soil properties and characteristics. (2) The acoustic data were adjusted for calibration and geometry factors and converted from analog to digital form for signal processing at UNH and Raytheon in computer-compatible formats. (3) Data processing and analytical formalisms were developed for examining acoustic signatures in the data bank, using both the field theoretic and a plane wave computer model of the soils, such as envelope detection, ensemble averaging, and similar statistical techniques. (4) Analysis and experiments on spatial variability created by movement of acoustic projectors and hydrophones were conducted. (5) Envelope detection techniques were developed and made operational which employ digital filtering techniques, including FFT's, to obtain the required Hilbert Transforms. (6) A power spectral analysis program to analyze acoustic data is operational. Several FFT approaches and window types and sizes were investigated to obtain the most effective algorithm. (7) Computer programs were written and tested to find system gains in the experimental program which correlate with the theoretical models. Optimization studies of these analyses of data subject to spatial and temporal variabilities continue.

The Development of an Exploration Systems Technology

A primary objective of Raytheon's participation in this project has been the ultimate development of a technology and an operating system for remote sediment classification. The state-of-the-art at the time of this project's initiation was obviously inadequate for system design. The work of the first two years in developing a theoretical model and a satisfactory data base were necessary prerequisites for such a design.

Today, it is possible to measure fairly reliably the quantitative vertical reflectivity coefficients of the first, second, and possibly additional layers, and establish the attenuation coefficients of the intervening sediments which are related to the porosity of the soils.

Third year system development objectives were to achieve a higher parametric sensitivity, through techniques such as oblique analysis, reduced data scattering through motion stabilization, and an expanded number of reliable parameters, to permit sediment characterization through a multi-element matrix description.

With the lessons learned from the experiments of the first two years, a prototype towed array measurement system was designed, developed, and tested, which provides fundamental data concerning near-surface sediments. Incorporated in the array are a series of discrete receiving elements which simultaneously sense the reflected acoustic response of each sedimentary layer over a range of incidence angles.

To improve the data quality, the array also incorporates specialized mechanical damping mechanisms and self-contained signal processing. Received signals are further processed by the shipboard portion of the system employing a Raytheon-designed processor which substantially increases the effective dynamic range of the acoustic signals recorded for subsequent computer analysis.

To date, the prototype system has been evaluated in relatively shallow water (150 feet), although there appears to be no technical limitation to increasing the operational capability to include greater water depths. Similarly, the subbottom penetration depths in excess of 60 feet now being achieved, could also be extended. The prototype system provides precise measurement of the compressional wave velocity in each of the first several layers with one-sigma precision of less than one per cent. Importantly, the velocity data are collected while conducting conventional subbottom profiling with the vessel traveling at speeds up to six knots.

Supported by Sea Grant, No. 4-20051-442.

The Undergraduate Ocean Projects Course

Course Director:
Professor Joseph B. Murdoch

The ocean engineering projects course at the University of New Hampshire was begun during the 1965-66 academic year and has been repeated each year since. The program has been funded since 1968-69 by Sea Grant. Thus, it is currently in its ninth year, and in its sixth year of Sea Grant funding.

The projects course is designed to provide the undergraduate student with an educational experience that he or she would not normally receive in the academic program—specifically, the experience of working as a member of an interdisciplinary team on a meaningful problem (usually in the ocean) under real-world constraints. Under the guidance of a faculty advisor, each student team is asked to define a problem, prepare and submit a budget, engage in dialogue with experts in the ocean community, deal with vendors, design and build a prototype model, test its design, and write a comprehensive report. Finally, an oral presentation and defense of the work is made with visual aids before a jury of experts drawn from the various sectors of the ocean community. Previous juries have included people from Benthos, EG & G, General Electric, Klein Associates, the Massachusetts Institute of Technology, New Hampshire State Agencies, Ocean Research Equipment, Office of Naval Research, and the Sea Grant Office of the National Oceanic and Atmospheric Administration.

Each spring the director of the projects course asks all ocean-oriented faculty to suggest projects for the following academic year. Juniors in the physical sciences, the biological sciences, and engineering are invited to attend a session where project ideas are presented by students or by the faculty members. Following an expression of preferences by the students, projects are chosen and the project teams are formed, every effort being made to insure interdisciplinary span in both teams and projects. In September, budgets are prepared and submitted. In October, monthly meetings begin at which each group reports its progress. These require each student to demonstrate his or her ability to state precisely and concisely what the team has accomplished to date.

In November the students begin to contact vendors and encounter such frustrations as items out of stock and delays in delivery dates. They develop the ability to improvise with less-than-optimal hardware. Toward spring the pressure of final design, testing, and report preparation occurs. In late April the date of the jury session is announced. Students prepare an abstract of their project report which is sent to each juror prior to the jury session in May. The jury session lasts a full afternoon. Each team is allotted 30 to 45 minutes to present its report. Following the jury session, an evening banquet gives the students an opportunity to become acquainted with the visiting jurors.

There were seven projects in the 1972-73 Projects Course. These involved 40 students from eight University disciplines: students from geography, zoology, business administration, political science, and engineering, co-advised by appropriate faculty.

Faculty members who have been involved with the projects course over the years are convinced that this form of education is valuable for any undergraduate student. We are therefore most grateful for continued Sea Grant support of this ocean project experience for our students.

A Diver Recall System

Advisor:
Professor Fletcher A. Blanchard

Consultants:
Professor Harry H. Hall, Professor Frederick G. Hochgraf

Technicians:
Mr. Richard D. Jennings; Mr. Donald MacLennan

Students:
Mr. Kenneth J. Chisholm, Electrical Engineering; Mr. F. Michael Doyle, Electrical Engineering; Mr. Ronnal P. Reichard, Mechanical Engineering

This project aimed to develop a simple, reliable method of contacting a diver in the water, to alert him to possible danger or to recall him to the support base. Two closely related systems were selected. The first system involves direct transmission of an audio signal into the water, relying on the diver's ear as the receiver. The second system transmits a frequency modulated signal and transfers it to the diver by a dual bone-phone mounted behind the diver's ears.

In addition to the usual problems of transmitting acoustic waves in seawater, diver communication signals are broken up and reflected by air bubbles, such as those created by exhalation through an open regulator system. These bubbles will break up the signal for both of the recall systems. With voice communication this would be a major obstacle, but with a repetitive warning signal, the signal will penetrate when the exhalation ceases and inhalation takes place. By using this type of communication the system is not dependent on instantaneous, continuous communication, but rather on eventual penetration. Finally, taking a lesson from the new police sirens, the pulsed signal is warbled, making it quite distinctive.

The primary system depends on the human ear for reception of the signal. In cold water the diver's wet suit includes a hood which presents a formidable damping effect on the signal. By limiting the use of the primary system to use in warmer waters where no hood is needed, this problem is overcome.

The human ear sustains a hearing loss of about 30 decibels upon entering water. In addition to this, there is a desensitization of the ear by the loud, periodic exhalation bubbles and inherent regulator noise during inhalation. Frequencies and magnitudes of these sounds were determined in the UNH swimming pool. The analysis of the data indicated that the transmission system should be designed to accommodate two types of signals, a signal centered at 1 kHz and having an FM bandwidth of 1 kHz. The second, a 20 kHz carrier, upon which is impressed a 2 kHz FM signal.

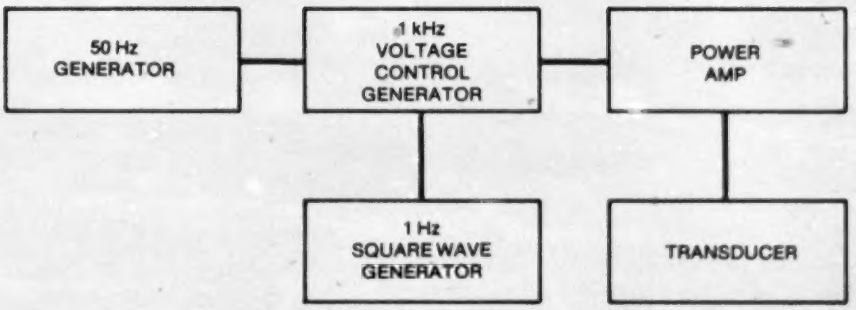
The Diver Recall System has been made available in two models. Model 1 is a portable unit which operates from a 24 volt, direct current, negative ground source. Model 2 is a permanent installation unit which is operated from a power source identical to that of Model 1. Model 1 and Model 2 have identical circuitry, each of which encompasses the primary and secondary methods of communication. The primary circuits of the transmitter consists of a 1 Hz sawtooth generator, a voltage controlled oscillator, a 1 Hz square wave astable multivibrator, a switch-

Diver Auditory Problems are Described

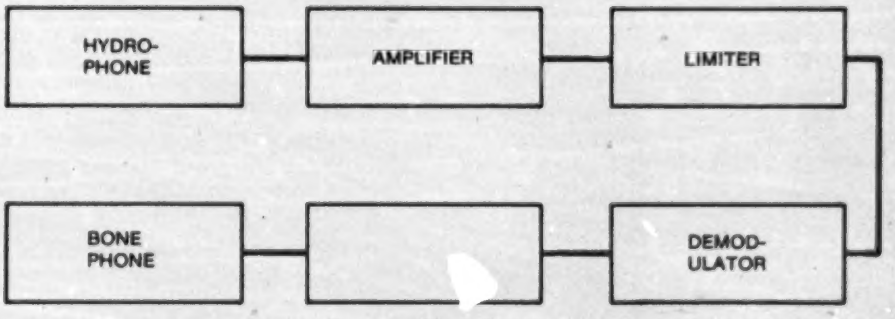
ing transistor, and a push-pull class B power amplifier. The secondary circuits consist of a single stage transistor amplifier used as a frequency modulation adjustment and buffer stage, also an audio output stage which delivers power to a set of headphones, and a third stage which consists of a preamp to the power amplifier stage.

The receiver of the diver recall system is designed to complement the transmitter of the same system. It receives the FM signal from the transmitter, demodulates the 2 kHz tone from the 20 kHz carrier, and then feeds it to the bone phones which are under the hood of the diver's wet suit. The tone that the diver hears is not unlike that of a telephone dial tone. By having this unusual tone applied directly to the bone phones, usual interference with diver hearing because of regulator and ambient sea noise is prevented. The designers believe that this system will allow a diver to enter the water with the confidence of having an adequate warning system.

At this time this system has not been tried under actual conditions. It has been bench tested and also tank tested. Under these conditions the receiver responded very well to the signal from the transmitter, and should provide an adequate signal for the diver. Pool and open water tests will be conducted on the system before it is judged to meet all design requirements.



Transmitter Block Diagram



Receiver Block Diagram

Anticipated Ecological Aspects of Artificial Reef Construction in New Hampshire

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Undergraduate Student:
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Our exploding world population has placed heavy demands on the seas which are expected to help feed us, receive unnumbered tons of waste, and provide recreational diversion. In many parts of the world, scientists, engineers, conservationists, and others have turned to man-made reefs to help the seas carry their burden.

Recreational planners have used man-made reefs to enhance sport fishing or to modify waves to a more favorable pattern for surfing. Conservationists and land developers have constructed reefs to protect shorelines. Fishery biologists seek greater harvests from the seas by modifying the environment with the construction of man-made reefs.

It is the purpose of this report to discuss some construction and ecological aspects of artificial reefs and relate these to a reef that could be built in New Hampshire. An artificial reef could be constructed in New Hampshire waters to protect stretches of eroding coastline, to serve as a recreational facility to enhance natural waves for surfing, to provide a safe area for snorkellers and scuba divers, or to attract game fish thus enhancing the sport fishing possibilities. Most importantly, however, an artificial reef could provide a protective haven for organisms vital to the economy of New England's fishing communities.

Artificial reefs already built were studied. Materials used in one constructed in the 1960's included 333 tons of quarry rock, 1 streetcar, 14 automobile bodies, and 44 concrete shelters. Its ecosystem, when studied about five years later, included over 200 species of invertebrates and 78 species of fishes. Fishing success was two to three times greater on the artificial reef than on nearby natural reef areas.

Factors that must be considered when evaluating various construction materials are cost, ease of handling at sea, durability, sufficient size to prevent sanding-in, and effectiveness as an artificial habitat. Thus, quarry rock, concrete rubble, automobile tires, junked automobiles, junked appliances, and baled solid wastes[1] are feasible materials for a man-made reef in New Hampshire.

Man-made reefs should be constructed upon firm, flat, relatively sterile sand or mud bottoms at a distance of over one-half mile from naturally occuring reefs. An artificial reef in New Hampshire could be constructed on nearly any offshore area, its depth depending on its purpose. To protect an endangered shoreline it would necessarily have to be located in shallow water. However, less than 10 feet of water would expose the reef inhabitants to unfavorable conditions.

Correlation of aerial photographs of the New Hampshire coast obtained by Project M.A.P.S. (a Sea Grant program) with a United States Geological Survey quadrangle map indicates that approximately 9¾ miles of sandy shoreline in New Hampshire could be used as appropriate sites for artificial reef construction.

An especially important factor promoting invertebrate colonization is the production of a stationary substrate. Artificial reefs provide this type of environment and support a diversity of organisms, especially sessile and semi-sessile organisms such as sponges, anemones, barnacles, and limpets. Once an artificial reef is constructed, shelter is provided by the cracks, crevices, and open spaces in the construction material, promoting colonization of reefs by the large benthic and mektonic organisms.

Early settlement on the artificial reef is a function of the number of larvae suspended in the surrounding water column. In later stages of development, settlement is increasingly influenced by the organisms already attached to the reef. This is especially true of the large benthic and vertebrate fishes, which seek shelter in the reef and feed on the organisms attached to the reef.

Invertebrate colonization of man-made reefs can be expected to occur in several stages. The first is the algal-bacterial stage. Chlorophyta (green algae), rhodophyta (red algae), and phaeophyta (brown algae) establish themselves along with various bacteria as a thin film on the surface of the reef material. This is followed by barnacle-hydroid, mollusk-polychaete, ascidian-sponge, and lastly encrusting ectoproct stages

In New Hampshire, a man-made reef could be constructed that would favorably modify the bottom relief and attract a large variety of marine species, and at the same time provide an outlet for junked automobiles, building rubble, and other wastes of an industrial society. Large fishes attracted to these reefs for protection and food could be caught by commercial and sport fishermen. Striped bass, codfish, lobsters, mackerel, crabs, and shrimp are just a few reef inhabitants that are sought for their commercial and sport-fishing potential.

[1]See page 17 of this report.

A Sewage Disposal Plan for New Castle, New Hampshire

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This project is a subjective study of the problem of human sewage disposal in the small quiescent community of New Castle, New Hampshire. The study shows that from a consideration of the present means of sewage disposal, New Castle is overpopulated and overdeveloped. This project proposes new methods to alleviate the sewage disposal problems that presently face the town.

This study in no way implies that New Castle, New Hampshire has a greater sewage disposal problem than any other coastal community. Its dense settlement, extremely poor soil conditions and the fact that it is surrounded by water and marshes, and its small size make it a logical choice for study as a typical seacoast community. Further, many residents have objected to the installation of community sanitation lines, but are dealing with the sewage disposal problem in other ways.

The town of New Castle, New Hampshire is on an island lying adjacent to Portsmouth, and was settled in 1623.

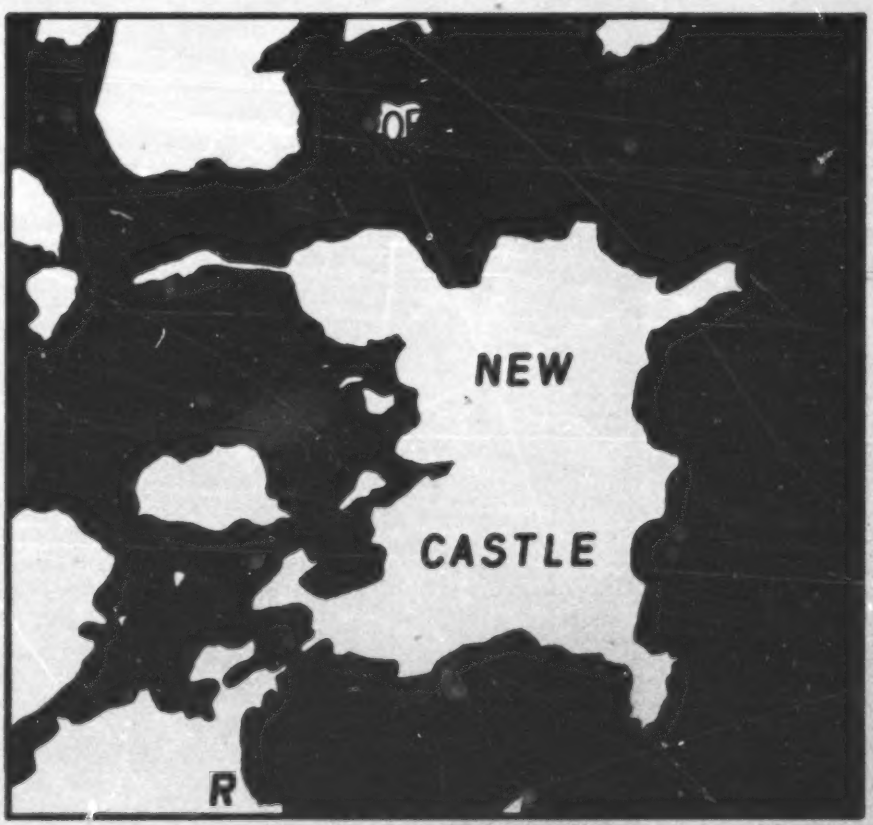
When evaluating New Castle with sewage disposal in mind, many difficulties are evident. As an old community, it is densely settled, with an uneven distribution of homes. With a population of about 1100, New Castle is overpopulated from a sewage disposal standpoint. The soils are poor for sewage disposal, and the ground water table is generally high. Shallow ledge and ledge outcroppings increase the severity of the problem.

Approximately 60 per cent of New Castle's 458 acres could be considered buildable. With New Hampshire Water Supply and Pollution Control Commission requirements of 1 acre lots for this soil, 291 lots are possible if conventional sewage disposal is used. With 320 lots now and an overabundance of antiquated subsurface sewage disposal systems, it is obvious that New Castle should allow new homes only where it can be shown that sewage disposal will not be a problem. The sentiments of the people being generally against the construction of a community sewage disposal system means that individual sewage disposal systems must be found to meet the demands of the widely variable soil conditions existing in the town.

If individual sewage disposal units are to be used, the soils and their permeabilities are of utmost importance. The degree to which the island will tolerate subsurface sewage disposal systems can be estimated from permeability of its soils. Percolation tests, which are essentially permeability tests done with water, are used in the state of New Hampshire as the sole means of determining absorption bed size.

Untreated household or industrial wastes will clog many, if not all absorption beds. A septic tank which puts raw sewage through a type of preliminary treatment and discharges a clarified effluent is frequently used. This is done so it may more readily percolate into the soils of an absorption bed. Most single family dwellings use a 1000 gallon septic tank.

Septic tanks conventionally deliver their effluents to leaching systems typically consisting of standard trenches, leaching pits, or absorption beds. Presently, because of ma-



New Castle and Surrounding Water Areas

terial and construction costs, absorption beds are universally used over the other two types of leaching systems. In New Hampshire, the size of the absorption area is determined solely by the percolation rate. Other regulations concern such features as the minimum depth below natural ground level, depth of rockfill or packing materia[1], spacing of the lines for distributing the effluent and minimum distance of the bottom of the bed above all ground water, ledge, or impermeable substratum. Conventional leaching beds just described are prone to failure. Common causes of failure are aging of the field, silt from the bed or overburden, breakage of subsurface distribution pipes, and root or biological growths.

Leaching field chamber systems give the homeowner a more effective leaching field with the important additional advantage of accessibility for servicing. These chambers, joined together, form a hollow underground cavern having a horizontal closed roof supported above the leaching field surface. This effectively triples the capacity of the leaching field and provides direct access to the leaching surface through manholes. These chambers increase aerobic conditions and eliminate anaerobic slime accumulation. The chambers prevent the major cause of leaching bed failures by completely eliminating the need for crushed stone and distribution pipes.

One make of leaching field chamber differs from the others in that it includes flow diffusers for metering flow of effluent to all areas of the absorption bed.

The advantages that leaching field chambers have over conventional absorption beds has led to a ruling by the New Hampshire Water Supply and Pollution Control Commission allowing reduction of the required size of an absorption bed by 40 per cent. Thus, in marginal areas, like New Castle, they should always be used in place of a conventional absorption bed.

The most recent development in the field of individual sewage disposal systems is the use of self-contained sewage treatment plants, which employ an extended aeration process. Self-contained plants employ aerobic microorganisms to remove organic wastes. These organisms use free oxygen and convert organic wastes to carbon dioxide and water. Self-contained plants are capable of producing effluent barely distinguishable from drinking water. One commercial model provides chlorination for the effluent where there is danger of high ground water.

The three design options offered in the preceeding pages could yield six varied subsurface sewage disposal systems. In order of increasing costs, they would be: (1) septic tank and conventional absorption bed; (2) septic tank and leaching field chambers; (3) septic tank and chambers with flow diffusers; (4) aeration plant and conventional absorption bed; (5) aeration plant and leaching field chambers; and (6) aeration plant and chambers with flow diffusers.

Probably the best system that a homeowner in New Castle could install would be the aeration plant and leaching field chambers with flow diffusers. In areas of good soil, a septic tank and conventional absorption bed would be adequate. Nevertheless, the sixth choice would definitely perform for a greater length of time than the first.

As an example of an optimum design, consider a lot of approximately 22,000 square feet off Laurel Lane in New Castle, New Hampshire having a 0 to 3 per cent slope. The soil classification is Hollis-Charlton. Actual percolation test data taken in June 1972 showed 18 minutes/inch at 36 inches.[2] A system, designed to agree with New Hampshire Water Supply and Pollution Control Commission specifications would require a 1200 gallon aeration plant, and a flow diffuser chamber bed of four rows of four chambers each (512 sq. ft.). The estimated cost, installed, would be $2241.15.

While the best way of handling domestic sewage is to collect it in sanitation sewer lines and to transport the sewage to modern, properly operated, central sewage plants, New Castle, New Hampshire, is an exception. Pollution is not universal on the island, and because of the difficulties in installing sanitation sewer lines in this community, an effective alternative must be used. From a study of the means available, the recommended optimum system should be the system just described. With a system of this type each individual home-owner will deal with his or her own problem and the expense will fall on those with whom the problem originates.

[1]Complete test data are not included here.

Conceptual Design of a System of Automatically Controlling Diver Decompression

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The University of New Hampshire's recompression chamber was constructed in 1968-69 as a student project. The chamber was successfully used in 1971 during the EDAL-HAB II project at the Isles of Shoals and in Project FLARE off the Florida coast in 1972. When in use, the pressure in the chamber is manually decreased in steps by the hyperbaric specialist who is in constant attendance. Oxygen and carbon dioxide levels and temperature have sometimes been monitored, but high flow rates have usually been employed to assure proper atmospheric conditions in lieu of precise monitoring instruments.

The purpose of this project was to alleviate some of the fatiguing [illegible] of manually controlled decompression by designing a system by which the decompression schedule may be programmed and then automatically followed by a system of pressure transducers and electronically controlled solenoid valves with provision for manual override at all times.

The UNH recompression chamber was originally designed as a portable unit. For the purposes of this project, it was decided to make the system dependent on the use of conventional 60 cycle power for use with the timer chosen.

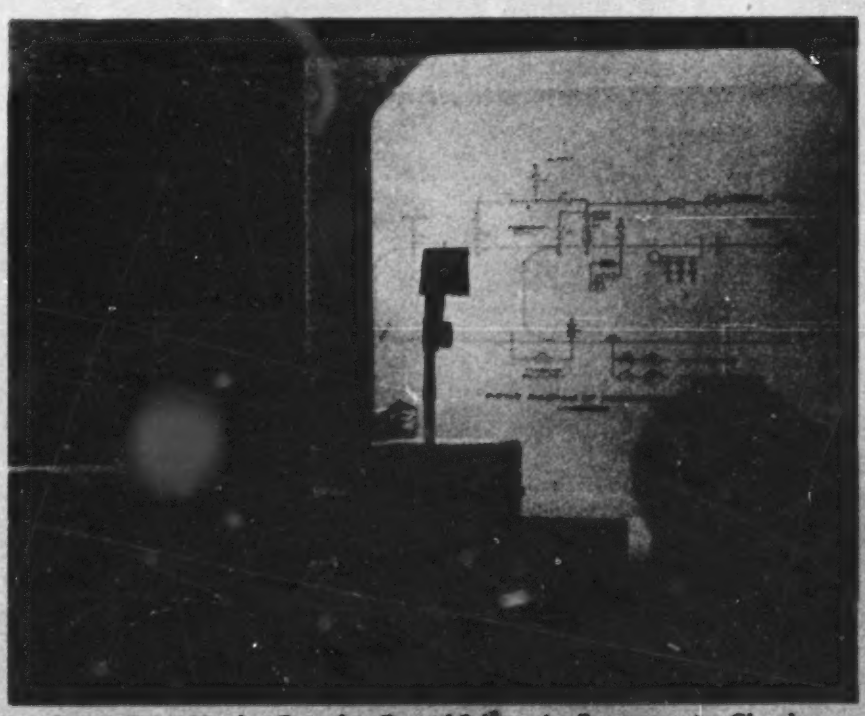
The Chamber

In a closed chamber inhabited by human beings, atmospheric conditions must be carefully controlled. Too high a partial pressure of oxygen for too long a period can cause oxygen poisoning. An overly humid atmosphere can make an already cramped recompression chamber seem even more suffocating. Serious also is an over-abundance of carbon dioxide. If low humidity air can be supplied, chamber humidity is usually not a problem and carbon dioxide concentration becomes the deciding factor in setting the flow-through rate for the chamber. The partial pressure of the carbon dioxide in the chamber should be held at a maximum of 0.005 atmospheres regardless of the chamber pressure. For two occupants in the chamber this requires a flushing rate of 10.0 cubic ft./min. measured at atmospheric pressure.

Pressure Control and Atmosphere Monitoring Equipment

The system chosen uses two main solenoid valves, one on the supply line and one on the exhaust line to control chamber pressure by adjusting flow rate. Two back-up solenoid valves and two back-up manual valves are also used, in case of failure of the main solenoid valves.

Dynisco, Westwood, Massachusetts, supplied a model pressure transducer having a range of 0 to 100 psia and having an error not greater than 0.05 per cent to monitor the chamber pressure. At the maximum design working pressure of the chamber (90 psi corresponding to 165 feet of seawater) this 0.05 per cent accuracy is equivalent to 0.45 psi or about 1 foot of seawater. A Beckman Model 715 Process Oxygen Monitor which has an operating pressure limit of 65 psia was made available to the project. An in-line flow assembly permits the monitor to be used in the exhaust line.



Project Team Member Describes Control Scheme for Recompression Chamber

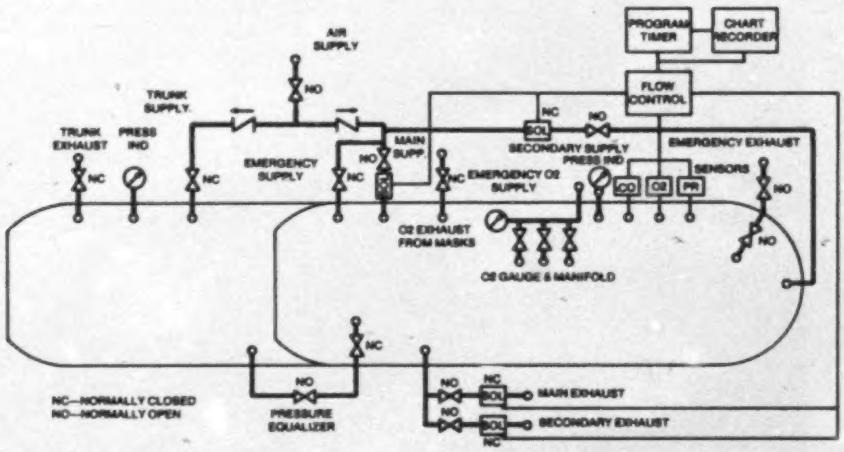
Scheduling Timer

The timing reference for the digital chamber controller is provided by a 60 Hz voltage source which is frequency divided to produce an accurate one pulse per minute signal. At each one minute interval a comparison is made between the chamber pressure and the pre-stored pressure vs. time data (decompression profile). The output of the pressure comparator drives the solenoid valves to control chamber pressure in accordance with the desired decompression schedule.

Conclusions and Recommendations

The project was carried through the design phase and much of the hardware installation was completed. The electronic timer/controller was not completed in time to evaluate the chamber control. It was not tested. However, the work done will provide a sound plan of action for future work which will make the recompression chamber an actual working chamber.

A few basic recommendations are: (1) The manual and automatic controls should be assembled together and a protective framework should be built around them. (2) A CO_2 monitor should be acquired. (3) The exhaust system should be modified to suit the pressure range of the available O_2 monitor.



Piping and Control Diagram of Recompression Chamber

Sagamore Creek—An Example of a Coastal Region Zoning Problem

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Sagamore Creek is a part of New Hampshire's coastal zone with problems probably similar to other coastal areas. It is a saltwater creek with headwaters in salt marshes near Route 1 about two miles south of the Portsmouth traffic circle. It empties into the waterway separating New Castle from the mainland, adjacent to Little Harbor. It is a safe haven for such small craft as lobster and pleasure boats. Its shores are zoned for both residential and commercial uses, and the lower half, from Sagamore bridge down, is already somewhat commercially developed, with a restaurant and a marina.

Some existing development is already detrimental to the Creek, polluting it or encroaching upon it. Strict control is necessary to protect the public's interest in this public resource—the water in the Creek and the real estate around it. Because of the nature of the political process strict control is difficult to achieve. Rational men do not easily yield their freedom to make a profit, and the public is only vaguely aware of what it has to lose. As a further complication there are many state agencies having some jurisdiction over New Hampshire's coastal regions. These include the Office of State Planning, the Fish and Game Department, the Department of Public Works and Highways, the Public Utilities Commission, the Water Resources Board, the Water Supply and Pollution Control Commission, and the New Hampshire Port Authority.

Not included in this, but perhaps most responsible for regulating the critical adjacent land use is the city of Portsmouth. The City Manager hires the City Planning Commission who can be said to work toward the public good. However, the Planning Commission may only professionally evaluate and recommend, and it remains up to the political body of the city to implement any policy. The city's interest lies in the benefit of its citizens, not directly with the good of the Creek. Politics being as they are, it is not surprising if revenue in the hand looks better than some future open space.

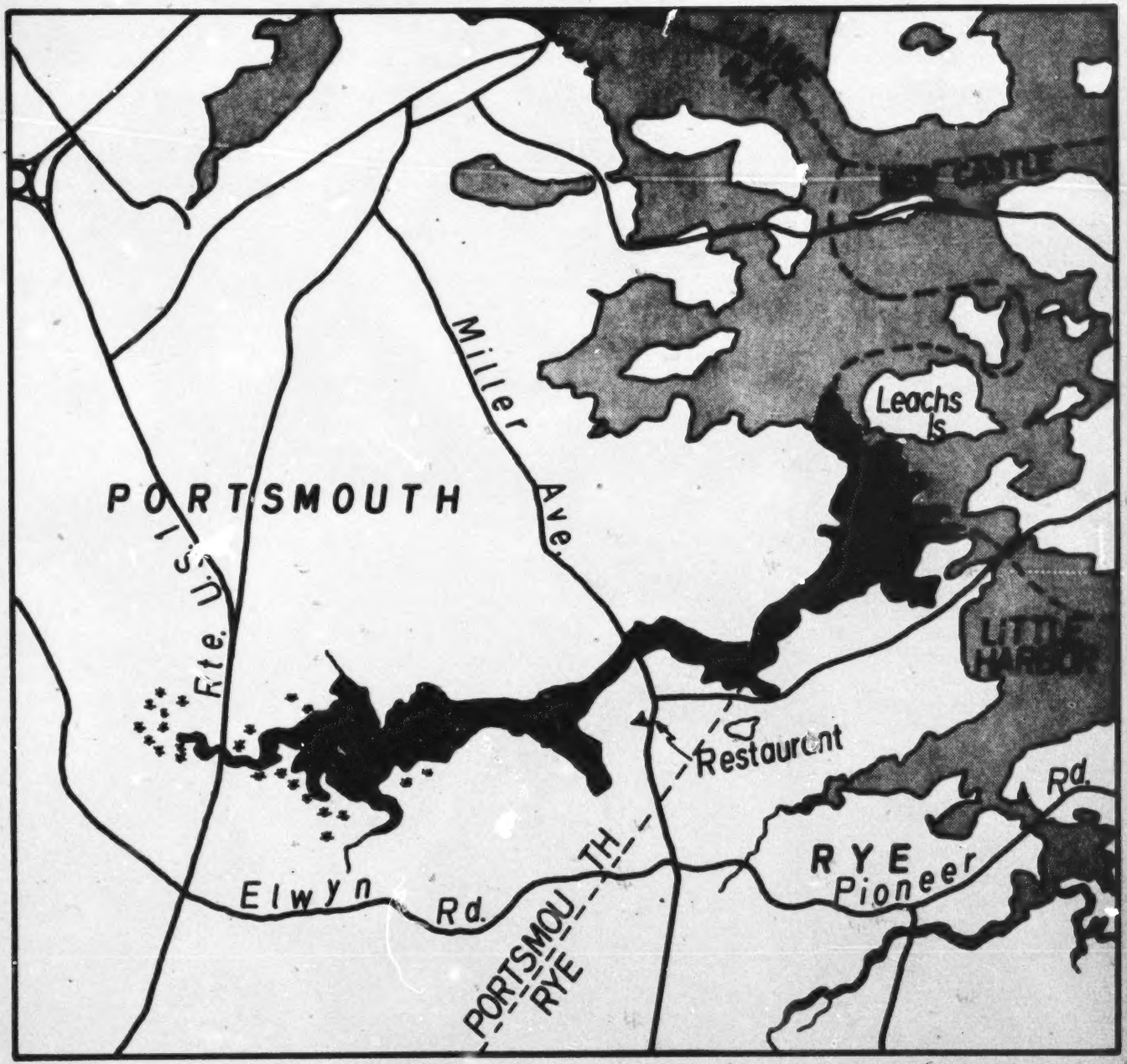
Where residential development has occurred, as in the Rye section near the mouth of the Creek, the effect has been the creation of some prime real estate. The owners certainly have an interest in preserving the quiet, rural character of their streets and stabilizing taxes.

In New Hampshire, belief in local government runs deep. Should the Creek be sacrificed on the altar of this tradition? Certainly without a clear plan for the Creek, it will be nibbled away with changes in zoning ordinances and discovered loopholes, lost in the tangle of competing interests, unregulated by agencies that hardly know of each other and have no funds for investing in the future.

Rather than fear the encroachment of government, New Hampshire citizens should demand that the government which claims jurisdiction must take the responsibility for maintaining the public treasure. It is foolish to lay the burden of motivation on concerned bird-watchers.

Perhaps a conference of all the agencies having some controls over the Creek and other coastal lands could agree on who would make policy decisions. If Sagamore Creek is filled in and paved over, who will bear the blame when the deed is done?

Jury Session Presentation—Coastal Zoning Problem



Relation of Sagamore Creek to Surrounding Communities

The Shallow Water Buoy Project

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Professor Ronald R. Clark

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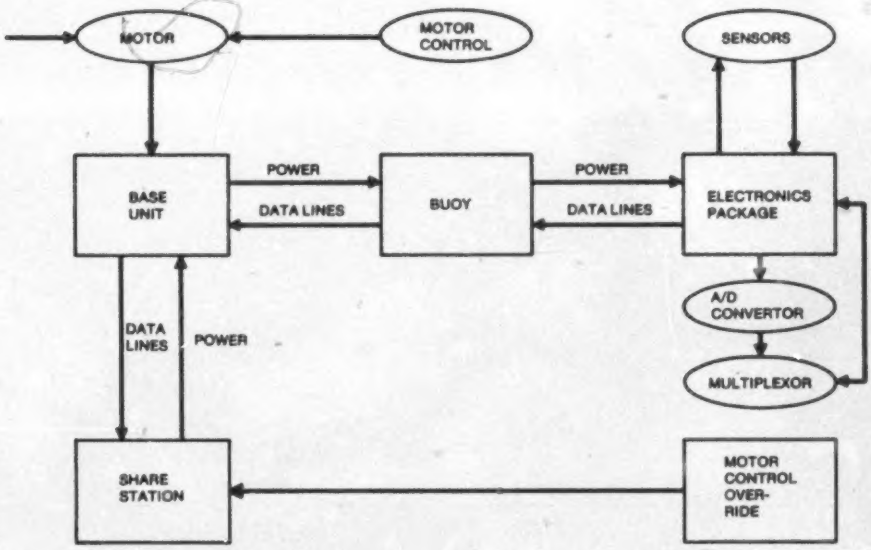
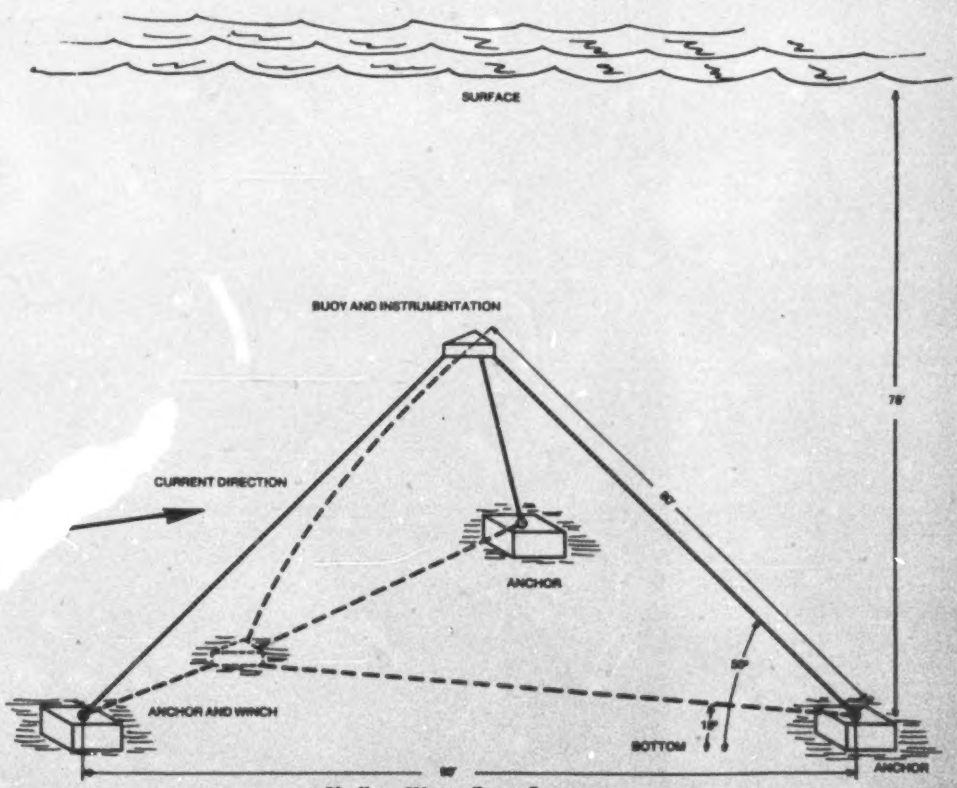


Shallow Water Buoy Block Diagram

The mission of this project is the development, construction, and deployment of a buoy system capable of independent long-term monitoring of estuary parameters. Individuals or companies conducting research in estuaries must have a means of analyzing these regions available to them. The analysis should yield information on such factors as the ecological impact of agriculture on recreational development of the estuary. The system described here, when developed further, will be capable of long-term monitoring of several interrelated parameters which can be used to understand the biological makeup of the area under study.

This project is planned to yield an operational system of interest to individuals or companies who will continue the development of estuarine buoy systems. Further work by engineering students now engaged on the project is planned.

The system will consist of exp mental and electronic packag tached to a triangular al um frame. This frame will be tethered to three anchor cables (legs), 120 degrees apart, anchored to the bay floor. Two of the legs will be of fixed length with the third attached to a motor winch assembly located



Shallow Water Buoy System

in the third anchor package. The motor winch assembly consists of a Bodine D-C Motor connected to a 15 inch diameter drum. The coiling of the third leg, varying the buoy depth, will be controlled by a clock timer and the d-c output from a pressure transducer located in the buoy package.

The electronics package is housed in an aluminum cylinder with O-ring sealed end caps. Circuit boards are mounted inside on an adjustable frame for easy servicing and modification.

The cylinder carries a temperature sensor in an oscillator circuit providing an output frequency proportional to water temperature. An inductively coupled salinometer projects from the side of the electronics package. This consists of two toroidal windings whose inductive coupling will vary with water conductivity. By combining temperature and conductivity readings a salinity measurement is obtained. A dissolved oxygen sensor utilizing a membrane covered polargraphic electrode as the detector is mounted in its own housing. Velocity of the water is determined by measuring the Doppler shift of a 10 megahertz sonic signal injected into the water from a housing mounted under the buoy. Turbidity is measured in another housing by measuring the light transmitted through the water from a source to a detector. The final package houses a pollution level indicator, utilizing the fact that organic compounds (indicators of pollution) exhibit very strong absorption characteristics for ultra-violet light.

The sensor outputs are frequency modulated for use in the 8 channel multiplexing transmission system, 7 data channels, and 1 synchronization channel. The data are transmitted to the shore station over the same cable used to provide power to the motor winch assembly and instrumentation packages.

To insure safety from damage by boats, the buoy has a shore-based motor winch over-ride circuit, enabling shore control of buoy depth. A light assembly that is activated as the buoy approaches the surface is mounted on top of the buoy for warning boats of the subsurface buoy. For protection from surface obstacles, a whip rod connected to a switch is mounted on the top of the buoy. If an obstacle is present, the rod will bend, activating a switch which turns off the winch motor. The buoy will stay at this level until the descent stage lowers the buoy.

Explaining the Instrumentation for the Shallow Water Buoy at the Jury Session.

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